ASSESSING THE INFLUENCE OF FARMERS' LEARNING ON WATER PRODUCTIVITY AND PROFITABILITY IN SMALLHOLDER IRRIGATION SCHEMES IN MALAWI

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By Elisha Gerry Jostone Vitsitsi

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Approval of the Thesis

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Doctor of Philosophy

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Abstract

ASSESSING THE INFLUENCE OF FARMERS' LEARNING ON WATER PRODUCTIVITY AND PROFITABILITY IN SMALLHOLDER IRRIGATION SCHEMES IN MALAWI

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With climate change and weather variability, there is presently a growing concern for food security and poverty reduction in many developing countries. The purpose of this work was to assess water productivity and profitability through farmer learning in selected smallholder irrigation schemes (SIS) in Malawi. The key question that directed this study was, "What difficulties and challenges hinder the transfer of modern irrigated farming technologies from the perspective of smallholder farmers in Malawi?" Agriculture being the engine of the economy, where the agricultural sector is dominated by smallholder farming systems large proportion of farmers face several restraints including water shortage and soil infertility thwarting viable crop production and food security.

The present study assessed the productivity and profitability of smallholder irrigated systems in the three selected SIS one in Dedza district and two in Chikwawa district and learned their determinants. These schemes selected because they were among the first to receive the devices and there are marked areas of drying specifically in the Lake Malawi region. And the lower Shire where the schemes are located. Both primary and secondary data were assembled and used in this research study. The primary data and information were collected through purposive and randomly selected 51 user-friendly device users and 66 non-user households from May to June 2021. Secondary data and information were amassed from a review of different works of literature both within and abroad. Descriptive statistics and econometric models were used to examine the data using Statistical Package for the Social Sciences software version 20.

The findings revealed that farmer learning using soil water monitoring devices increased crop productivity and is profitable. Water use efficiency helps suitable water resources management. Water application experience, time, and attendance spent in scheme meetings were pertinent and had a bearing on the productivity and profitability of the irrigated farming system. Based on the findings, farmer learning is identified as decisive for food security improvement and poverty reduction. It can, therefore, be concluded that farmer learning has an encouraging and considerable influence on household food security and poverty reduction.

Keywords*:* Climate Change, Farmer, Farmer Learning, Household Profitability, Influence, Irrigation Scheme, Crop Productivity, Monitoring Devices Soil Nutrient, Soil Water, Malawi.

Declaration

I declare that the thesis has been composed by myself and that the work has not been submitted for any other degree or professional qualification. I confirm that the work submitted is my own, except where work that has formed part of jointly-authored publications has been included. My contributions and those of the other authors to this work are explicitly indicated below. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others. No parts of this work have been published in any of the books, journals, etc.

AI Acknowledgment

I would like to present that I have not used any artificial intelligence (AI) tools to create, proofread or produce any text or ideas related to any draft or final versions of the thesis.

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Dedication

To smallholder farmers in Malawi and the numerous individuals interested in irrigated farming, whose water-inefficient actions, prompted the conduct of this research study. This thesis pursues an improvement in crop productivity and profitability of smallholder farmers by lessening water application in irrigation schemes globally. Besides, policy and decision makers harmonise their meticulous work with applicable technical and legal guidelines underpinned by scientifically proven research study facts to increase water use efficiency and sustain irrigation development.

To all my beloved ones who have gone ahead to be with the Lord and those who sustained the discomforts and agony of my derisory attention while I embarked on this relevant research investigation to uplift the lives of rural people who form the majority of Malawi's citizens. To them, I say, the Almighty God through Our Lord had already planned for this and let us be part of His Glory. The very best is yet to come.

Acknowledgement

The research study entitled “Assessing Water Productivity and Profitability through Farmer Learning in Selected SIS in Malawi” is my work and effort that was motivated by the extensive food security vulnerability and widespread poverty of rural people in Malawi. It has been a long journey from the time I wished I enrolled in a Doctor of Philosophy (PhD) programme way back when I obtained my Master of Science Degree in Soil and Water Conservation Engineering in 1997. Many people encouraged me to pursue this and I would like to acknowledge their efforts that made this project successful.

First, I wish to express my thoughtful appreciation and distinct honour to my supervisor, Dr Ursula Schinzel who guided me from Dissertation Part 1 planning to the end of Part 4. I also extend my gratitude to other lecturers who helped me to understand ethical issues that are relevant to dealing with people. Societal coercion wields a robust effect on smallholder crop producers, especially contrary to their viewpoints. Since this research considered an evaluation of water use efficiency which is one of the many factors that has effects on social acceptance of technology utilisation, social capital, therefore, can trigger the adoption of soil water and nutrient monitoring devices by collective social interaction and reinforcing farmers’ perceived self-confidence.

My esteemed supervisor, Dr Ursula Schinzel, thank you for directing me in the right way and for the support provided in good and bad times throughout the research conduct. Also, thanks to officers in the School of Doctoral Studies who favourably considered the extension of assignment submissions when I lost many relatives. To Mdachita, even though you were not officially my field supervisor but a counterpart, I do not know what I could have done without you. It was great to see you supporting me when sometimes I was weak and encouraging me to carry on the work and I appreciate a lot the advice you gave not to fall into the devil's trap. Let me quote

two verses in the Bible 2 Timothy 4 verses 7 and 8 "I have fought the good fight, I have finished the race, I have kept the faith. Now there is in store for me the crown of righteousness, which the Lord, the righteous Judge, will award to me on that day and not only to me but also to all who have longed for his appearing."

Learning from the smallholder farmers provided me with insights that I know why it is difficult for some of the poorest farmers to remain as they are. Visiting them in their irrigation schemes may be a difficult thing to do without transport. Being a self-sponsored student, I faced challenges that were overcome through the help of many colleagues. I managed to cope and visited the farmers. McDonald Chikhawo I cannot thank you more than enough for driving me to the research study sites and taking your time off from your important work. It was so lovely of you to consider helping me, thank you once again. Dr Darwin Singa my Office mate I wish to thank you for the previous development efforts in the Agricultural Engineering Department at Bunda College of Agriculture as you stood solidly with me throughout. Indeed, you are such a friend in need.

Lastly, I wish also to recognise my family and friends, especially for their support and moral encouragement during the research period. You showed love and provided me strength and courage to forge ahead. Above all, of course, thanks and the greatest exaltation be to God the Almighty for guiding my efforts throughout, as exemplified in the Shepherd's Crucible.

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List of Abbreviations

AI	Artificial Intelligence
AfDB	African Development Bank
ASWAp	Agriculture Sector Wide Approach
CFG	Control Farmer Group
CFS	Committee on World Food Security
CC	Climate Change
COVID-19	Coronavirus Disease of 2019
DARS	Department of Agricultural Research Services
ELT	Experiential Learning Theory
FAO	Food and Agriculture Organisation
FGD	Focus Group Discussions
HIV/AIDS	Human Immunodeficiency Virus and Acquired Immunodeficiency Syndrome
IFAD	International Fund for Agricultural Development
IWRM	Integrated Water Resources Management
IWMI	International Water Management Institute
MLR	Multiple Linear Regression
PSM	Propensity Score Matching
ODK	Open Data Kit
OLS	Ordinary Least-Squares
SAR	Southern African Region
SPSS	Statistical Package for the Social Sciences
SIS	Smallholder Irrigation Schemes

SIRP	Smallholder Irrigation Revitalization Programme
SSA	Sub-Saharan Africa
TFG	Technology Farmer Group
TPB	Theory of Planned Behavior

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CHAPTER 1: INTRODUCTION

Introduction

Several challenges and problems of persistent natural resources degradation and growing population pressure are being faced at global, regional, and local scales that are influencing the expanding need for food and fibre. However, these demands cannot be met because of the increasing shortage of freshwater resources (Padder and conference Bashir, 2023). The scarcity of water resources is attributed to the evolving trends in climate change and variability, increased human population, appropriate technology absence, and socioeconomic characteristics, with nearly one-third of the total worldwide population experiencing water scarcity (Dolan et al., 2021; Damkjaer and Taylor, 2017).

Nutritious food is a pertinent requirement for all manner of humans that should be fulfilled for a healthy and productive life. Matters associated with food security vis-à-vis accessibility, reasonability, sustainability, and ease of use remain relevant issues for policymakers and other stakeholders that are linked to national economic development (Lawlis et al., 2018; Aborisade and Bach, 2014). CFS (2017) claimed that food security must prevail when people, always, have physical, social and economic access to adequate, harmless and nutritive food to meet their nutritional necessities and tastes for a lively and vigorous life. Appreciating the structural and fundamental causes of food insecurity and famine is essential to recognise and prioritise activities to stimulate food security initiatives and the right to satisfactory food requirements for all people. On the other hand, a family may be food insecure if it can fail to meet, purchase, or have access to adequate quantity and better quality of food. Food insecurity is a social and economic condition where a household has limited or uncertain access to adequate food. The absence of these facts may contribute to dreadful health and physical concerns (Omotayo, 2020).

Appropriate water for irrigation and scarcity are among the most worldwide risks currently being experienced due to climate change, increased population growth, and environmental pollution (Felter and Robinson, 2021). Nearly 70 percent of the total freshwater is used in irrigation systems annually, however, rainfall has been erratic in many countries, particularly in Sub-Saharan Africa (SSA) (Abou Zaki et al., 2018). Additionally, the ability of the prevailing irrigation approaches is in the range of 50 and 60 percent, which is not sufficient. Consequently, improving water use efficiency is a very significant suggestion for feeding the increased human growth and handling the water crisis. From a historical point of view, there has been a narrow motivation for smallholder farmers in Malawi to improve water use efficiency, since the on-plot variable vis-à-vis volumetric water used was not charged, it was and is free and more importantly, there is inadequate supervisory control of water resources management in SIS. Several factors have resulted in applying too much water and conflicts. Some issues are as follows:

Availability of water abundance promotes conjunctive use for abstraction and dismal regulatory water allocation process. Conjunctive water use discusses the synchronised use of both surface water and groundwater to meet crops' water demands (Banda et al., 2020). This historic water abundance has had limited competition for water in irrigation schemes and there was no monitoring of water allocation systems because the maximum water available over a season to a smallholder farmer far exceeded crop requirements. At that time, it resulted in a slight incentive to apply water efficiently. Amplified and challenging demands for water application on irrigation schemes, and water-associated services and the consequent pressures on the available water resources are contributing to growing attention towards water allocation through monitoring. Thus, conjunctive water use, the practice of utilising surface and ground water resources together to improve the reliability and availability of water for human use is therefore important.

It is widely reported that climate change results in increasingly erratic and low rainfall, mainly in areas where food insecurity is very high and significantly affects vulnerable groups (Ali et al., 2017; Sauer and Tchale, 2009; Sauer and Zilberman, 2009). As a result, the poor will suffer the most and will need inexpensive and user-friendly strategies to acclimatise to unreliable weather. This acclimatisation needs to consider not just water scarcity and droughts, but also the amplified chances of life-threatening events like floods (Nicholson and Selato, 2000). Increasing water shortage has at present increased the limited use of water for crop development. Water source use conflicts have risen suddenly in SIS in the country and elsewhere in recent years (Stedman et al., 2018; Tafesse, 2003). The strategic driver behind the emergence of water allocation interest worldwide has been the general and continued growth in water resources utilisation for food, primarily because of population and national economic growth as well as changing consumption patterns.

Smallholder farmers form an imperative part of the worldwide farming community; however, they are frequently ignored. Over 80 percent of the projected half-billion small gardens are managed by the smallholders providing over 80 percent of food to emerging nations, contributing considerably to lessening poverty and food insecurity. Worth noting is that water consumption increased fourfold during the last century affecting nearly 3.6 billion of the global population (Galhena et al., 2013). Yet, some parts of the world are food insecure. Out of nearly 7 billion, about 870 million people are experiencing food insecurity according to Tasgheer et al. (2024). Wani et al. (2009) noted that approximately 60 percent of the food-insecure people live in South Asia and sub-Saharan Africa. The majority of farmers in the sub-Saharan African region depend largely on rain-fed agriculture and finding the means and opportunities to use less water and increase productivity can be a game-changer. Technology integration can therefore transform farming practices thereby contributing to increased efficiency and sustainability.

Climate variability is causing unprecedented problems and challenges, particularly in those countries in sub-Saharan Africa generally and Malawi particularly that depend on rain-fed agriculture (Vitsitsi, 2019). Even though agricultural production experienced a rapid expansion between the late 1960s and early 2000s due to modern farming practices in Malawi which were supported by extension message delivery, the situation is completely different now. Besides, the Human Immunodeficiency Virus and Acquired Immunodeficiency Syndrome (HIV/AIDS) attrition has robbed the front-line staff who were responsible for demonstrating new agricultural messages and techniques (Cammack, 2004; Freedman and Porku, 2005; Phiri et al., 2012). The introduction of innovations is fundamental to national economic and developmental processes. For modern technology to be accepted and used by people, particularly in agriculture, it must be familiarised and adapted to the circumstances experienced by the majority of smallholder farmers (Behera and France 2023; Cramb, 2000; Watson, 2008).

According to Philip et al. (2014), the characteristics of new technologies are generally not transparent and not well understood by the would-be new users since rain-fed agriculture fluctuates, locally regionally, and internationally (Dinar et al., 2019). Worth noting is that water consumption during the last century increased fourfold from affecting 0.24 billion people (14 percent) to 3.8 billion (58 percent) of the current global population (Kummu et al., 2016). Numerous reports are available and different approaches to water resources management have been reported. For example, FAO produced a set of training materials to help smallholder irrigation farmers compute water requirements (Nakawuka, Langan, et al., 2018). Previously, smallholder farmers never applied technologies to decide on tolerable water volume to be applied. Due to its inaccessibility and shortage, ne3w irrigation technologies are often cited as pivotal to boosting water use efficiency and lessening the use of scarce agricultural inputs, whilst sustaining prevailing farm production levels, mainly in arid and semi-arid agricultural areas (Oki and Kanae, 2006; Panda et al., 2004).

It is noted that instead of developing modern small irrigation schemes, there is a need to use less water than before as it is a well-known fact that irrigation is the largest user of freshwater (Koech and Langat, 2018; Koech et al., 2015; Playan et al., 2018). The majority of irrigation schemes in Malawi were established by the government to convey irrigation water to smallholder plots but were seldom consulted during the phases of irrigation design construction and maintenance (Kishindo, 2006; Mulwafu et al., 2003). Since the irrigators consider water as a gift where it is not charged, but they only contribute funds for canal maintenance and other governmental fees, too much of it is used sometimes unnecessarily.

Agricultural productivity and its influence on economic development, food security improvement, and poverty reduction rely on the services given by well-performing ecosystems consisting of water delivery, soil fertility, and soil conservation. Devices to measure soil moisture content were and are being designed for use by irrigation engineers and scientists. However, they operate from unalike mental views based on theory, which supports explicit contact among themselves. Farmers, instead, based on practice and local knowledge by creating mental constructs that allow water application on crop conditions (Abel et al., 1998). Due to climate change and water scarcity, farmers need to apply ample water for crops to grow well. So, farmer-friendly tools are valuable to base water application decisions (Mwamakamba et al., 2017).

The introduction of innovations is fundamental to national economic and developmental processes. For modern technology to be accepted and used by people, particularly in agriculture, it must be familiarised and adapted to the circumstances experienced by the majority of smallholder farmers (Behera and France 2023; Cramb, 2000; Watson, 2008). Efficient water use in irrigated farming and new technologies *help smallholder farmers improve their living by allowing for more productive use of inputs, particularly water and fertilisers* (Ogunniyi et al., 2018; Salazar and Rand, 2016).

Statement of the Problem

Achieving the food and fibre quests of a rising worldwide population is a huge challenge due to climate change which is responsible for severe water scarcity for irrigated farming. The irrigated farming sector aims to meet growing food demands with a significant reduction of associated crop water consumption. Thus, increasing crop productivity with a drop of water using innovative technology is the way forward in the twenty-first century (Dinar et al., 2019). Particularly, poverty and food insecurity are some of the major causes of concern in Malawi where nearly 62 percent of the population is multi-dimensionally poor with the intensity of poverty close to 55 percent, this means that poor people face, on average, more than half of the weighted affluence deprivations. The Multidimensional Poverty Index, a product of the incidence and intensity of poverty is 0.337 in the country.(NSO et al., 2022).

Smallholder irrigation systems are recognised as important common pool resources that are needed to increase crop productivity and sustain livelihoods in water-shortage areas (Akuriba et al., 2020). Improving irrigated farming and increasing productivity through raising water use efficiency is one of the key approaches for reducing poverty and bettering the livelihoods of rural communities in which the majority depend either directly or indirectly on rain-fed farming. It is, nonetheless, widely recognised that Malawi is currently facing an unprecedented water crisis due to climate change and variability (Mataya et al., 2020; Vincent et al., 2017). Without developments in water resources management particularly in irrigated farming systems, water-related challenges and problems are anticipated to significantly worsen and will considerably affect the welfare of the resource-poor farmers who regularly end up bearing a disparate share of the costs (Ingrao et al., 2023).

The common irrigated farming practice in SIS in Malawi includes an open-loop control system where there are no real-time water application programmes. The operator vis-à-vis a farmer decides on the volume and time the irrigation will take place. The water application control action is, therefore, autonomous of the water application process. Thus, a farmer's decision to apply adequate water is influenced by personal and environmental factors concerning needs (efficiency misunderstanding, need compatibility), awareness (importance, benefits and weaknesses), and available information (knowledge, awareness). In such a situation, farmers adopt poor water application strategies that influence scheme operations by losing huge water quantities through deep percolation and promoting the leaching of beneficial nutrients from the root zone and also conflict.

Water use in many SIS has been recognised to be misused through which too much is applied than required (Irmak et al., 2011; Kissawike, 2008; Salman et al., 2020). This situation can be compared to the central heating boiler which is controlled only by a timer facilitating heat that is applied for a constant time, regardless of the temperature of the building (Lomas et al., 2018). Similar to the boiler system, in the irrigation water control system in irrigation systems, the operator, who is the smallholder farmer, decides on the water quantity to be applied and the frequency of the irrigation event (A. K. Singh et al., 2022). Also, it generally rests on the observation and farmer experience about plot soil characteristics instead of the physical field conditions like soil water content and more importantly weather variability that may lead to excessive or insufficient water application (Tzanakakiset al., 2020).

Water use in many SIS is noted to be misused whereby too much is applied than required. As a consequence, soil nutrients and applied fertilisers are leached from the soil rendering it less fertile (Keraita and Cofie, 2014; Mateo-Sagasta et al., 2013). Low soil fertility results in low productivity and farmers' profitability, which are the key current issues in Malawi's irrigated agriculture. Assessing water productivity and profitability through farmer learning in selected SIS in Malawi is a thing in the right direction.

The field capacity concept provides misleading conduct in the water application. Most water monitoring devices are designed based on this concept, however. Farmers, in SIS, who intend to achieve food security and reduce their poverty levels need to learn and overcome water application abuse and increase water use efficiency. Access to training, appropriate technologies, and a conducive environment may make a difference in whether or not they can successfully manage and increase water-use efficiency. Besides, observing and emulating, technologies and better farming methods that are presumed to increase crop productivity can be predicated on two key players namely the farmers as decision-makers and extension field support as grassroots government staff (BenYishay and Mobarak, 2013). Nonetheless, the ultimate approval or refusal to accept the idea of using new methods depends exclusively on a farmer's attitude toward the new technology. At this level, farmer learning using that new technology becomes relevant. In this respect, knowledge from the social sciences provides a stratagem, a human-driven pattern that expounds the selection process and human behaviours concerning technology use. More importantly, there still is less intelligibility on what stimulates the impetus to select the technology among smallholder farmers and what supports or hinders their adoption decisions (Ton and Proctor, 2013).

The need to reduce poverty, enhance food insecurity, improve resilience to climate variability (Vitsitsi, 2019), and increase economic growth (Pittock et al., 2018), most African countries and donors alike are devoting billions of financial resources to new irrigation investments. People's perception is a vital element in irrigation development. The People-Centred Approach is a developmental idea that can support irrigation development and circumvent food insecurity and poverty incidences (Bwalya et al., 2009; Nagan, 2016; Bleidorn et al., 2013).

Generally, the research study intended to identify the rate at which farmers not using user-friendly soil water and nutrient monitoring technologies are learning and understanding the effectiveness of reducing water use to circumvent household food insecurity and poverty.

Published research has focused largely on technological aspects of measuring soil water content, such as tensiometers, time domain reflectometers, neutron probes, and gypsum blocks or electrical resistance blocks which illiterate farmers are unable to interpret (Sharma, 2018; Evett, 2007). Increasing water use efficiency is a solution to frequent drought occurrences as it is one of the most challenging issues restricting crop production and influencing food insecurity globally generally and in Malawi particularly. Increasing water use efficiency is a solution to frequent drought occurrences as it is one of the most challenging issues restricting crop production and influencing food insecurity globally generally and in Malawi particularly.

It has been observed and crucially noted that public-private endeavours to promote the adoption of user-friendly tools that enhance agricultural productivity have neither yielded substantial adoption rates nor contributed to overall crop yield increases among smallholder farmers in developing countries (Wise, 2020). Dismal experiential research has been conducted that has examined smallholder farmers' attitudes towards the utilisation of new user-friendly technologies and farmer learning has not received in-depth attention in the literature. For example, previous empirical studies have ordinarily focused on demographic factors (such as age, gender, education, and income) in determining how farmers adopt or non-adopt new agricultural innovations (Kamruzzaman et al. 2020; Ruzzanteet al., 2021). Since farmers in irrigation schemes are the intended beneficiaries of the new user-friendly soil water and nutrient monitoring tools to increase crop yields and reduce fertiliser use, an extensive understanding of their adoption behaviour may influence and inform decision-makers on how to plan agricultural extension intervention and design appropriate dissemination programmes.

Irrigated agriculture's main objective is to supply sufficient water to crops and should be able to equalise atmospheric water demand with what is extracted from the soil. When water is applied to the soil surface it infiltrates into the soil and reallocates under the potential gradient effect (Ferreira et al., 2015; Liste and White 2008; Zhang et al., 2018). The campaign for the promotion of new technologies in irrigated agriculture by public and private institution providers has not just catapulted improvements in crop productivity but they have also increased household revenue and well-being among smallholder farmers in developing countries (Okori et al., 2022).

The main practical challenges for the influence of farmer learning in smallholder irrigation systems include understanding factors, poor water infrastructure, and water scarcity. Regarding socio-economic problems, high cost of modern irrigation systems, insufficient credit facilities, and market inaccessibility. On the other hand, the formal challenges consist of the existence of a diverse legal structure, farmers' derisory participation that include women farmers, and ailing irrigation water user associations. Nevertheless, the future of a revolutionised irrigation expansion is bright through climate change adaptation strategies like soil water and nutrient monitoring tools as well as rainwater harvesting technologies.

To clearly understand the issues that influence and/or impede farmer learning, a well-conceptualised study to describe the issues that may affect farmers in their decisions to participate in learning how to use and adopt (or not adopt) user-friendly soil water and nutrient monitoring tools can solve some of the challenges and influence policy decision makers to consider supporting such initiatives. The researcher, therefore, selected Bwanje Valley, Khamalathu, and Mulunga, the three SIS, to assess the relevance of use user-friendly soil water and nutrient monitoring tools. These tools help farmers make better decisions about their crops, informing them of timely and adequately applying water, which can lead to more efficient use of resources and a reduced environmental impact. Some of the problems being experienced in these schemes include among others low crop productivity through excessive water application loss of essential nutrients by leaching, and conflicts due to water abstractions by farmers located upstream.

Justification of Scheme Selection

Initially, Bwanje Valley Scheme started, by local farmers, holding rainy water to grow rice during the rainy season and maize during the dry season utilising residual moisture left behind by the floods. After noticing the commitment made by farmers, the Malawi Government in 2000 upgraded the canal network with donor funding. The results had been encouraging; however, climate change has influenced water scarcity and negatively impacted crop harvests. This necessitated identification of approaches to circumvent this situation

For the sustainable productivity and profitability of irrigation facilities, the Department of Agricultural Research and Services (DARS) with donor partners planned, institutionalised and encouraged the adoption of soil water and nutrient monitoring devices to help farmers to apply water adequately based on data that is scientifically relevant. This study was, therefore, conducted to assess the productivity and profitability in the Bwanje valley, Khamalathu and Mulunga small scale irrigation schemes in Chikwawa and Dedza Districts as case studies. Due to time and financial resources, these schemes were selected to form part of the investigation that received the user-friendly soil water and nutrient monitoring devices. Besides, Chikwawa district located in the Shire Valley experiences low rainfall, and climate change is expected to exacerbate this issue. Climate change poses a substantial challenge to the area, where communities have depended on rain-fed agriculture for years. This research study, hence, focussed on using the devices to assess crop productivity and profitability, which are key solutions for sustainable agriculture development.

Purpose of the Study

The purpose of this study is to assess water productivity and profitability through farmer learning in selected SIS in Malawi. As soil water availability is of greater importance particularly because it influences crop growth and crop production, a carefully planned investigative study to identify interactive linkages to water application and crop productivity will provide thorough perceptions of how farmers utilising farmer-friendly water monitoring tools benefit and whether neighbours, who are not using these tools, are emulating what their fellow farmers are doing. The main objective of irrigation implicitly is to provide crops grown with adequate water to prevent stress that may induce a reduction in crop productivity and a very poor quality of crop harvest (Morison et al., 2008; Woodhouse et al., 2017). The irrigation required timing and quantity of water application are commonly controlled by the existing climatic conditions soil water content, crop's stage of growth, and the root zone development. The foregone statement determined the water delivery policy on an irrigation scheme with their influence on labour, crops grown, etc. through effective water management (Replogle et al., 1983).

Nature and Significance of the Study

An understanding of the underlying causes of low farmer participation in learning how to improve crop productivity by user-friendly soil water and nutrient monitoring technology adoption rates in SIS in Malawi would be the key to the future design of any irrigated farming interventions. Any intervention promotion gained from the understanding of how farmers perceive the benefits accrued from the new technologies and farming practices would be vital information for the design of SIS (Ruzzante et al., 2021). Research is a human activity based on rational consideration of substance investigation in an organised and systematic manner to discover plausible solutions to problems and challenges (Beddington et al., 2012; Onuka & Onabamiro, 2010). Thus, scientific studies involve several different techniques of research approaches. This research is within the environmental setting as such its approach to assembling data and information sought to undertake the normative base for environmental concerns in order to explain social phenomena (Ekins and Zenghelis, 2021).

It has been postulated that in the coming years, the irrigated farming sector will require more water to produce enough food grains to satisfy the unprecedentedly increasing food demand of a growing population. Conversely, the actual water availability will be reduced and its supply is projected at just half of the demand by the year 2050 (Le Mouël and Forslund, 2017; Srivastava et al., 2012). To produce enough food and fibre crops, there is a need to have data that has been researched thoroughly to base investment. This study aims to contribute to knowledge, drawing on experiences of SIS about how farmers manage water resources and increase water use efficiency. Specifically, to understand how the soil and water nutrient tools help in reducing water application, whether there is improvement in crop productivity in circumventing food insecurity as well as to identify socioeconomic factors that have significant relevance for farmers participating in learning just to mention but a few. Based on representative national data and information *most smallholder farmers in Malawi have no opportunity to easily access irrigation facilities and remain extremely reliant on* rain-fed *farming.*

The current research falls within the social research domain. Social research is a systematic and ordered examination of a social challenge and/or problem that needs a resolution. It is a type of study used to consider individuals, groups of people, and institutions. It is research on, and with, human beings in the real world, one of social studies' sensational components. The social skills and perceptions researchers bring to the research as members of society are also essential ingredients of the research process. Conley and Christopher (2001) claimed that the nature of the study means that much social research comprises direct interaction with respondents. This is a crucial variance between social science and other scientific research, like biology, engineering or geology, which is not given the prominence it deserves. Effective researchers' skills, that is, honest liking of interacting with others, simplicity in verbal and written communication, and, perhaps most notably, heeding skills, are important but often ignored qualities for good social research.

The mixed-method research approach was adopted to assemble information to respond to the research questions. Methodologically, it is an approach that integrates qualitative and quantitative styles that bring attributes of both that can improve the understanding of farmer learning by providing a more comprehensive picture of better water resources management than either method can alone. This study considered appreciating and understanding how farmers were learning from their peers using soil water and nutrient monitoring tools to appreciate and understand their perceptions on water resources management and water use efficiency to improve crop production and profitability at the household level.

According to Creswell and Clark, (2017), there are six reasons for combining qualitative and quantitative methods: a) sole data and information sources may be inadequate; b) primary findings require to be described and clarified; c) tentative findings of each have to be comprehensive; d) a complementary approach of the methods may improve research findings; d) a hypothetical approach is largely used with quantitative and qualitative findings; e) several research phases may support each other to be appreciated and f) a clear understanding of research objectives is paramount. Accordingly, these reasons have led to the advent of typologies that aim at mixing the diverse purposes that have appealed to using mixed methods research (Bryman, 2006). Usually, two stages were employed in a mixed methods approach. The first was a qualitative stage that explored other issues that influence crop productivity and profitability of irrigated farming through structured interviews. The second was a quantitative stage that examined the relationships between the two constructs (farmer learning and water resources use). The basis for the study was a typology adopted by Greene et al. (1989) that has also been illuminated by several authors (Clark & Ivankova, 2016; Creswell & Clark, 2017a; Creswell & Creswell, 2017; Tashakkori & Teddlie, 2008)

This initial chapter has provided background and some important realities relating to irrigated farming and farmer capacity in SIS in Malawi. These facts suggest that there are a very large number of smallholder farmers in Malawi that are not aware of how they can increase water use efficiency which has a greater effect on household crop productivity and profitability. The absence of necessary information on water resources use efficiency presents challenges in the communication to improve water resources management and how smallholder farmers can be able to relate rainfall erraticism. These farmers carry a huge responsibility in managing available water resources and overcoming food insecurity and poverty based on farmer learning that can enable them to reach the maximum of their potential and achievement. Since Malawi's economy is agriculturally based, expansion of irrigated farming is, therefore, inescapable and farmer learning is the vital pillar that the country is precisely trying to solidify so that the living standards of the people can improve.

A research study of strategic implementation for water resources management through farmer learning using user-friendly soil water and nutrient monitoring tools in smallholder irrigation systems is important for several reasons. First, there is a knowledge gap. Parry et al. (2020) argued that several SIS are defective and dysfunctional so farmer learning and accepting new technologies are required to expedite supportable transitions. Implementing emerging user-friendly water monitoring tools is particularly uncertain for public agencies because vital success factors have neither been investigated satisfactorily nor documented adequately. Second, agricultural research for development and therefore a strategy implementation has gained momentous focus with the passage of the Malawi National Irrigation Policy (DoI, 2016). Third, the research study could also help to compare the factors that influence farmer learning implementation to the approach itself, for commitments to designing strategic farmer learning models for future research studies. The national policy requires that irrigation development should be harmonised with other policy developments at regional as well as local levels.

The development of new SIS, therefore, necessitates tactical plans that should include specific performance indicators tying goals and objectives to the environmental conditions. It is recognised that all development comes out of the investigation. Reservation is sometimes better than pride, for it has alluded to the fact that it leads to examination and analyses, and the outcome of analyses leads to discovery. The foregone is premised on a popular Hudson Maxim in circumstances of which, the research implication can well be assumed. Amplified research studies make progress and development possible in some particular disciplines.

Research indoctrinates scientific and inductive opinion and it encourages the progress of rational habits of thoughtful decisions and organisation. As such, this investigation creates a point of reference for assessing the importance of increasing the water use efficiency of the current as well as future irrigated farming activities in the smallholder schemes. The depletion of irrigation resources heightens the need to increase water use efficiency. It generates the empirical evidence required to facilitate the improvement of economic use of irrigation water in the Scheme, which will help improve the overall basin-wide and subsequently national water resource productivity. Notably, smallholder farmers lack expertise, poor and a sense of solidity amongst themselves. They are mostly illiterate and some are engaged only in subsistence farming (Kapari et al., 2023). Nonetheless, the government is intensifying smallholder irrigation growth by adopting new skills and policies.

The role of smallholder irrigation in improving a country's food security, prosperity, and stimulating economic growth is well established (Bosc et al., 2013; Gollin, 2014; Shiferaw et al., 2009). Malawi is one of the poorest countries in the world. The Human Development Index score for 2018 was 0.485, which is in the low human development category positioned at 172 out of 189 countries and territories (Outlook, 2018). However, between 1990 and 2018, the country's Human Development Index value improved from 0.303 to 0.485, an increase of 60 percent. While Malawi's population living below the international poverty line of US$2/day has slightly declined from 72 percent in 2010 to 70 percent in 2016 much needs to be done particularly in the agricultural sector. Agriculture remains the backbone of the economy employing nearly half of those in paid employment. It supports at least 81 percent of the population and contributes more than 30 percent to the gross domestic product and over 90 percent of export earnings. Accordingly, the investigation is significant in that it offers a decision platform for policy-makers and those working in the agricultural sector to act as springboards to enable smallholder farmers to adopt suitable instruments for supporting performance in their irrigated farming activities.

Climate change has been identified to increasingly affect food security and drive many households into destitution, particularly in developing countries (Vitsitsi, 2019). Currently, all nations are intertwined into a global village and what happens in both developed and developing countries may have influences that affect migration of people to seek better livelihood prospects elsewhere. This fact remains a challenge for trade, policy-makers, and researchers who need to resolve and bring stable performance and sustainable competitive advantages in productivity and profitability. This, therefore, compels, a steadfast need to reframe strategies to use water resources effectively for crop water productivity targeting smallholder farmers who are the majority in the emergent nation.

Essentially, the study sought to contribute to water resources management in the wake of climate change and variability that induces water scarcity, destitution, and hunger (Vitsitsi, 2019). The research process drew upon smallholder farmers' experiences and examined irrigation practices of an evolving harmony about social learning and irrigation development as outlined in current syntheses of the water resources management and water use efficiency research through the utilisation of modern technologies to increase crop productivity and farmer's profitability (Aramburu et al., 2019; Elijah & Odiyo, 2020; Genius et al., 2014a). At a local scheme level, the findings are important for the farmers to change their behaviour in how water resources could be managed in terms of increasing water use efficiency and behaviours that can sustain scheme performance, thus, leading to food security, survival and improved affluence. While at the national level, the findings have the potential to influence the design of nationwide irrigated farming development policies and practices. More importantly to influence the delivery of information and training of farmers in increasing irrigation water use efficiency. Moreover, appreciating farmers' attitudes towards new agricultural technologies in the irrigation sector might offer insight into how smallholder farmers make their technology adoption (or non-adoption) decision choices.

This dissertation will, therefore, help fill a literature gap in water resources management. It will define a list of common factors acting in the conservation of the environment and will contribute to filling a gap in increasing water use efficiency for irrigated farming sector institutions. Briefly, for anyone who wants to understand how water resources management improves crop production and increases profitability, this study should prove useful. The quality of learning environments and their relevance in their functions and influence is an evolving area in irrigation research. Farmer learning is about using authentic real-life environments. As such, the experiential learning by making use of irrigation facilities will enable farmers to benefit from acquired skills.

Research Contribution to Farmer Learning Literature

Previous research efforts have acknowledged a range of technical and non-technical factors that have significant influences on the adoption and use of water use efficiency technologies by smallholder farmers, however, the prevailing research studies continue to contribute insufficient attention to the broader environmental complex that smallholder irrigation systems need to fit into. There is, thus, a greater need for thorough research on the social factors that influence water resources management adoption and the benefits the requisite technologies provide, along with the interaction between these factors. Especially, there is a need to assess the effect of social differentiation on the context within which water use efficiency technology corresponds, which in turn is possible to influence the factors that influence the adoption of water use efficiency technologies and increase crop productivity and profitability that they may provide to enhance smallholder livelihoods. Thus, key contributions of this research study include firstly the methodology implemented in the investigation of water productivity and profitability is robust and can simply be applied to other SIS. Accordingly, this research study can help in creating a methodology which can be applied across different SIS in developing countries and adjusted for different situations. Secondly, given the narrow volume of research conducted on the simple water and nutrient monitoring tools in SAR and Malawi even less on water use efficiencies, this research study can also help in setting and providing the basis for other possible future research studies in technology adoption.

This research being an experiential investigation of the adoption and use of water efficiency technologies by farmers in SIS, a phenomenological investigation of farmers' individual lived experiences can lead to a more holistic appreciation of the intersectionality of challenges they face. Their experiences can assist extension staff and academia in identifying what drives decision-making surrounding irrigated farming, technology acceptance, and challenges associated with farmers (Stone, 2019). Through learning apprehension of the reasons individuals choose to or not to adopt a technology can be recognised. The importance and influence of individual circumstances on the decision to accept and use a new technology can be addressed particularly by looking at an individual’s behaviours. Most people are capable of learning not only from their experiences but also from the practices of those within their surroundings (Bandura, 1986). Thus, a priori-learning in technology use can be important in irrigated farming to improve water resources management and increase crop productivity and ultimately profitability

The perceptions gained from this research study contribute to water use efficiency literature examining the approval, adoption and use of water efficiency technologies in irrigated farming in Sub-Saharan Africa generally and Malawi particularly. The main purpose of this research is to assess water productivity and profitability through farmer learning to influence the use of water efficiency technologies by farmers in SIS and how they interact with their peers and to explore what evidence prevails to support claims regarding the nature of crop productivity and profitability in improving livelihood that these technologies are expected to provide. Table 1.1 shows the rational and reliable association between the investigation’s objectives, questions, and informs the approaches. The main research question is: “What difficulties and challenges hinder the transfer of modern irrigated farming technologies from the perspective of smallholder farmers in Malawi.

Table 1.1

Research Problem, Statement, Purpose and Questions

Problem Statement	Purpose Statement	Research Questions
▪ The first issue is the question of food insecurity and poverty as experienced by farmers in selected SIS in Malawi.	▪ To examine food insecurity and poverty as experienced by farmers in selected SIS that influence farmers to participate in farmer learning.	▪ How do farmers describe food insecurity and poverty experiences in selected SIS?
▪ The second issue concerns the effect of low crop productivity and profitability on the lived experiences of farmers.	▪ To explore the effect of low crop productivity and profitability.	▪ How do farmers explain the effects of low crop productivity and profitability in their households?
▪ Lastly, the third issue is about the complexities of technology's role in improving food security and household income.	▪ To scrutinise how easily and difficult user-friendly soil water and nutrient monitoring tools play in improving food security and household income.	▪ How do farmers express their experiences with user-friendly soil water and nutrient monitoring tools in improving food security and household income?

Three problems were formulated with each having its objective fulfilled through a series of research questions that are addressed through the course of this dissertation.

The Objective of the Study

The main objective of the study was to assess the perceptions and attitudes of smallholder farmers and how they learned about the benefits of user-friendly soil water and nutrient monitoring tools towards water resources management and fertiliser conservation in selected SIS in Malawi. From the agricultural innovation point of view, water use efficiency was used as a proxy applied for improved crop productivity and increased household revenue.

Based on the above, the first issue identified as a basis for this study concerned the question of food insecurity and poverty as experienced by farmers in SIS by examining farmers' circumstances and experiences of food insecurity and poverty. The second issue was to investigate the effect of low crop productivity and profitability on the farmers' lived experience and what effect low crop productivity and profitability have on their lifestyles. Lastly, the third issue was to explore the complexities of technology's role in food security and poverty through farmers' descriptions of their experience of low crop productivity and profitability. These can be translated into the following main research objectives:

- To determine factors influencing smallholder farmers' participation in farmer learning towards the acceptance and adoption of user-friendly soil water monitoring tools.
- To examine the benefits of farmer learning on the adoption of user-friendly soil water and nutrient monitoring tools.
- To provide farmers perceptions on the usefulness and benefits of user-friendly soil water and nutrient technology learning to improve crop productivity and profitability.

The Specific Objectives are as follows:

a) To examine the relationship between farmer learning and farming practices influencing household food security and income;

b) To investigate socio-economic characteristics affecting farmer learning to improve water resources management and water use efficiency;

c) To determine the significance of farmer learning to fight household food insecurity and poverty;

d) To assess the role of institutional arrangements on farmer learning to improve water resources management and increase water use efficiency; and

e) To identify and evaluate the impacts of farmer learning on water resources management and poverty reduction.

Research Questions and Research Hypotheses

Although it is commonly acclaimed to include research questions and hypotheses in social and legal research, it's not always necessary or appropriate to do so. In this research both research questions and hypotheses were used simply because the research hypotheses were a consequent of the research questions (Nizamuddin et al., 2017). The decision to use both was based on the research type, objectives, and the precise question of the research study. The crucial issue was to illuminate the precise nature of the challenge and/or problem to be solved. In this case was to understand whether the tools introduced in the SIS improves water use efficiency and crop productivity. Thus, the key question was, therefore, "What difficulties and challenges hinder the transfer of modern irrigated farming technologies from the perspective of smallholder farmers in Malawi?" The technology transmission process is steered by government policies, actions, measures and principles involved in the process and need to be thoroughly explored and examined (Barsky, 2017).

Three main questions directed the conduct of this study that used a mixed-methods research design. The position of the mixed-methods approach in scientific research is very clear, that is to understand and appreciate the circumstances under study (the what), implication, rules, and values (the why or how) within a single research question integrating the strength of two different methods (qualitative and quantitative) and suggests several ways of considering the research question under investigation. The purpose of this mixed-method study was to determine farmers' needs and preferences for technology integration into their irrigated farming systems. Smallholder farmers' behaviour is varied and is manifested in the manner in which they interpreted farming and engage in agricultural practices. Therefore, three key research questions were investigated:

RQ1

What factors (farmers' attitudes and perceptions) determine smallholder farmers' households' participation in farmer learning towards the acceptance and adoption of user-friendly soil water monitoring tools?

RQ2

What benefits do user-friendly soil water and nutrient monitoring tools have to improve productivity and profitability in SIS?

RQ3

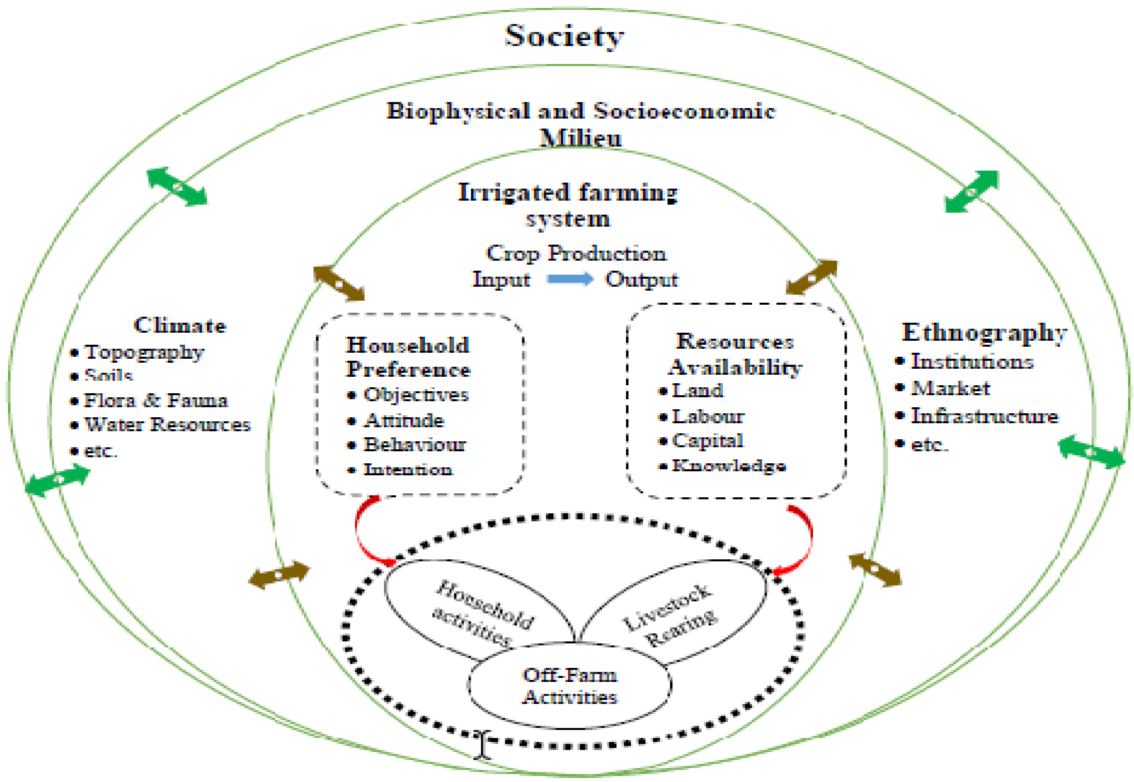
How do farmers perceive the usefulness and benefits of user-friendly soil water and nutrient technology learning to improve crop productivity and profitability?

It is crucial for farmers to intensify adoption of sustainable water practices to improving water productivity and profitability at household level. Castillo et al. (2021) incorporated hypothetical framework that reflects shared, mental, and profitable influences. It is noted that research consists of identifying and explaining problems experienced, framing hypothesis(es) or suggesting solutions through data gathering, arranging and analysing data to make deductions and reach a reasonable conclusion guided by hypothesis(es). A hypothesis is a supposition from a rational analysis of previous studies. It is a combined word from two Greek words: ‘Hypo’ meaning ‘tentative’ and ‘thesis’ meaning ‘usual opinion’. The word ‘hypothesis' means a tentative opinion about a solution to a challenge or problem. Some authors have defined hypotheses as guesses made to solve problems experienced (Satendra, 2005; Wellek, 2010). This research considered the environmental conditions as the starting point that can strongly influence irrigated farming activities in amassing data and information. Figure 1.1 above shows the relevance of learning among smallholder farmers as construed by the researcher. It indicates pertinent learning processes at the smallholder farmer’s disposal in the learning environment, rooted in the present patterns and paradigms of agricultural innovation and sustainable agriculture. The researcher initially explored the concept of farmer vis-à-vis peer learning and its processes in educational and agricultural literature.

Peer learning in the agriculture sector describes a process through which smallholder farmers and other agricultural professionals come together to learn from each other by sharing knowledge, information, experiences, and best practices through group discussions, field demonstrations, field visits or farmer-led learning groups, permitting and encouraging the them to acquire understandings and improve their farming practices in a trusted and relatable environment; fundamentally, learning from peers experiencing similar challenges and with similar circumstances. The main principle is that smallholder farmers can learn treasured lessons from other farmers who have successfully and effectively tackled comparable challenges and they adopted innovative practices on their own farms that have proved wanting. Since the knowledge is shared emerging from within the geographic area, the information acquired is directly relevant to the local climate, soil types, and market demands. Regular meetings where smallholder farmers share experiences, ask questions, and collectively solve problem are important.

Figure 1.1

Sociocultural and environmental settings in irrigated farming systems.

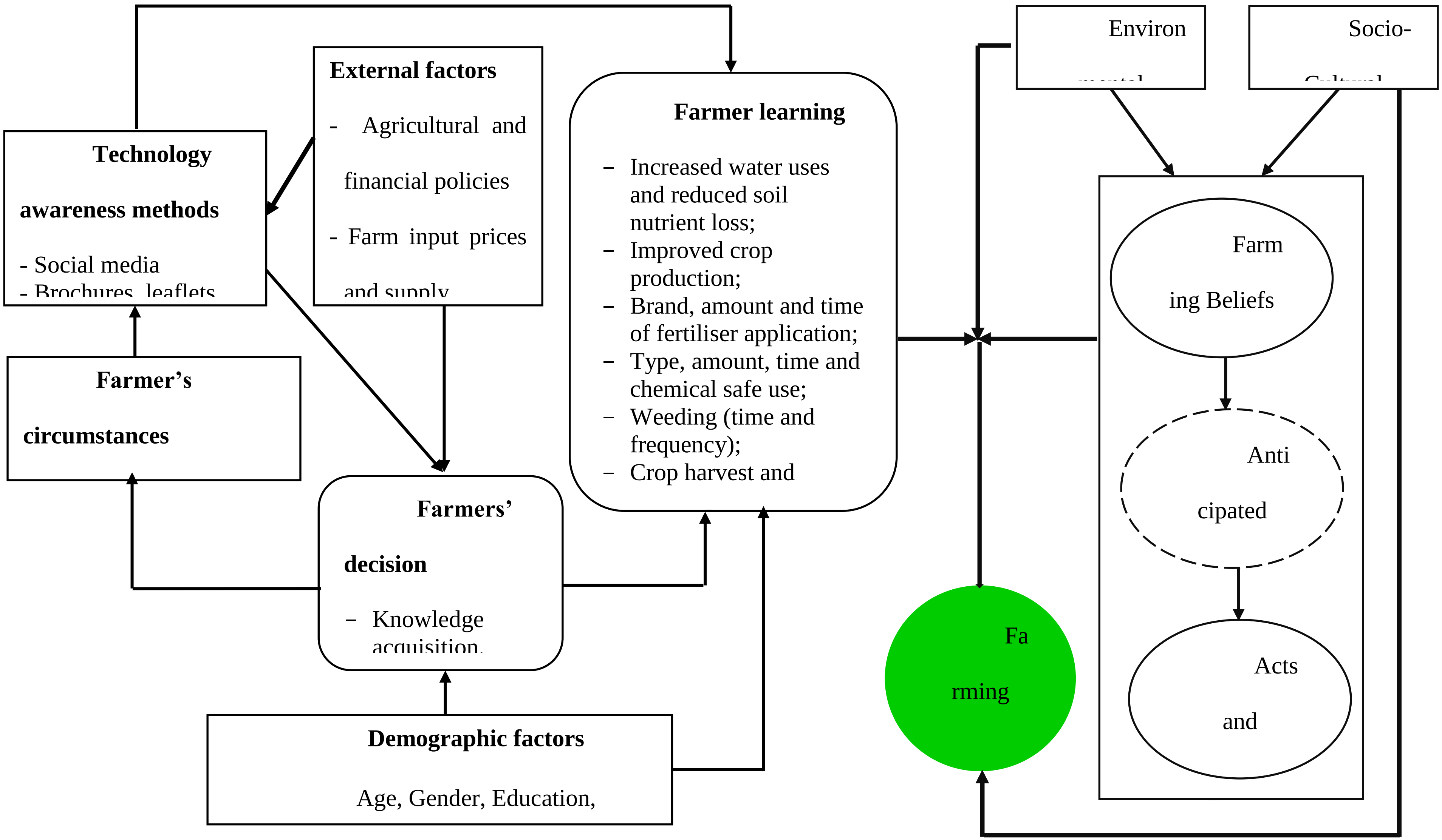


A suggested conceptual framework illustrating how knowledge and beliefs are constructed and how they can predict, influence decision-making processes and subsequent actions has been well considered. Environmental and socio-cultural issues contribute to developing principles about irrigated farming dynamics leading to personal differences in perceptions relevant to irrigated farming development. Experience with local environmental situations, in most cases, influence interpretations of the functioning and interrelationship between weather, soil, and crop production related to irrigated farming as they collect and translate this information in their minds overtime (Aouadi et al., 2015). Furthermore, real-world experiences are mediated by socio-cultural factors, for instance, society norms and anticipations, which, influence what information is relevant and the behaviours that inspire collection and translation of the environmental characteristics overtime.

Smallholder farmers use the acquired agricultural beliefs as a foundation for envisaging the outcomes of farming practices in terms of factors like soil fertility status, crop yield, food security, and household income that can influence household decision-making in farmer learning participation in order to take applicable actions and adopt appropriate behaviours (Kapari et al., 2023). Thus, crop productivity which may or may not agree with the expected results, may create positive or negative feedback that would either reinforce technology adoption or make changes in the agricultural practice perceptions through farmer learning to adapt opinions, expected outcomes, and behavioural change, correspondingly. It is proposed that this feedback as displayed in the conceptual; framework would ultimately vary the environmental and socio-cultural circumstances on SIS (Figure 1.2).

Figure 1.2

Conceptual Structure for Understanding Farmer Learning and Factors Influence Skill Acquisition



To corroborate these ideas in the context of irrigation, this research study focused on the introduction of simple water and nutrient tools as expert's agricultural belief systems of suitable water application and communities practicing irrigated farming in SIS. Specifically, the researcher investigated the difference in understanding of proper water application with a particular focus on three groups of farmers: (1) farmers using the introduced tools (users); (2) farmers emulating the users but on the same facility and (3) farmers who did not know the water application devices. By measuring the differences and perceptions of water application in these farmer groups, the researcher intended to demonstrate how different understandings of the dynamics of irrigated farming systems found between communities can characterise decision-making concerning water application approaches and water resources management practices. Farmer perception assessment from different participant groups can detect knowledge gaps and contrasting beliefs. Isolating gaps in knowledge or understanding of a matter can benefit researchers to focus their efforts on issues where more information is needed leading to innovation discovery of better value and will enable and enhance information sharing, contribute to perfect communication, and support the development of collective ownership of water application plans (Izuchukwu et al., 2023). Attaining this information, research experts and extension staff can improve adoption approaches or extension materials in concurrence with the farm communities.

To corroborate the relevance of the introduced devices in the context of SIS in Malawi, this research study focused on understanding water application practices and farmers' practicing irrigated farming. Specifically, the researcher focused on assessing the differences in farmer behaviour with particular focus on water application approaches followed by three different farmer groups: (1) users of soil water and nutrient monitoring devices (2) emulators of users and (3) control group. By evaluating the differences in these behaviours, the researcher intended to illustrate how different understandings of the dynamics of water resources management found between farming communities can shape decision-making concerning water application methods, and farming practices. A comparison of mental models from different participant groups can detect knowledge vis-à-vis learning gaps and incongruent views. These recognised gaps will facilitate and improve information sharing, contribute to perfect message dissemination, and eventually support the development of shared water resources management and conservation plans (Kalogiannidis et al., 2023). With this information, research experts, extension staff and farmers can develop adoption strategies or extension materials to instil confidence in water application. Based on the above, therefore, the following hypotheses have been formulated:

H1

Farmers' access to learning is unrelated to agricultural technology adoption. Conversely, the application of better farming practices based on farmer learning will affect food security unless there are ignored or falsely observed situations that are key bases of neighbours' outcomes.

H2

There is a relationship between socioeconomic characteristics and farmer learning to improve water resources management and increase water use efficiency.

H3

Food security and household income are linked to farmer learning how to increase water use efficiency.

H4

Farmer learning using new innovative ideas and methods under various institutional arrangements does not influence water use efficiency and reduces food insecurity and poverty levels.

H5

Farmer learning by adopting user-friendly soil water and nutrient monitoring tools is expected to significantly improve water resources management and increase water use efficiency

Personal Reasons for this Study

This study for me, personally, is not only a contribution to knowledge and research but it is also a topic that is very close to my heart. Farmer learning to increase water use efficiency can project substantial changes to local, national, regional and global water resources management and these changes can have associated influences on livelihoods. Notably, there are two primary concerns related to food security in households, particularly among smallholder farmers: prevalent hunger and malnourishment underpinned by the mismanagement of natural resources and ecosystems.

I have spent almost half of my life working in the field of water resources management. My Master of Science Degree is in soil and water conservation engineering discipline. I have been a tutor and lecturer working in colleges and training centres under the government and the university respectively. I have seen and worked with a large number of illiterate smallholder farmers and also experienced a range of practices in irrigated farming. Suitable devices that are available to improve water resources management and adoption of these have been my key motivation to investigate whether the devices introduced in Malawi that uneducated farmers are using in selected irrigation schemes can change their well-being.

My conviction has always been to manage natural resources with particular emphasis on imparting knowledge and skills to individuals, including farmers themselves, extension field assistants, or students. My specific interests have always been in finding out how they feel about their roles in environmental management. Experiential learning has often been discussed particularly in terms of how smallholder farmers are affected if their learning is hands-on. It is a process of learning by doing. By engaging farmers in practical involvement and reflection, they can connect theories and knowledge learned during demonstrations to real-world situations. I was attracted to find more deep-rooted issues regarding food insecurity and poverty levels prevailing in the country and recognised that certain concepts can help to circumvent the challenges faced with water shortage and, therefore, try and understand how these farmers consider their roles and capabilities.

When I read Kolb's experiential learning theory (Kolb, 2015), I related it to my experiences and what was happening in the irrigated farming sector, and this urged me to assess water productivity and profitability through farmer learning in selected SIS in Malawi. Irrigated farming methods have great effects on water consumption, crop productivity and household income. Literature has revealed that participation in farmer learning activities generates knowledge to deal with water resources management as well as crop value chain challenges. Hence, learning and training are perceived to be two of the most influential armaments in the fight against poverty and economic development particularly in the rural areas where farmers live. If the majority of smallholder farmers can accept and use the technologies that lessen water use, it can be one of the happiest citizens.

Thesis Overview

Chapter one presents the background, statement of the problems, purpose, objectives, and significance of this research study. Chapter two outlines the literature review that helped to identify the theories that impinge on the farmer knowledge capacity and water use efficiency practice gaps. Essentially adoption of technology and its influence on house welfare in Africa, Smallholder farmers' circumstances and social learning among smallholder agricultural farmers, technology use impact on household food security and poverty as well as institutional and organisational characteristics are outlined and develops initial concerns to consider the relevance of institutional capacity for managing water resources and to improve crop production and household income. Chapter three discusses the methodology of this research study, its nature and the research design and approach taken, the research instrument and data collection processes have been highlighted. Crucially operationalisation of research variables, ethical considerations, processes, and assurances are dully considered. Chapter Four initially presents the questionnaire validation that was used to assemble data and information followed by research findings. These research findings are based on the questions and hypotheses. Chapter Five presents the summary of the broad conclusions of the investigation addressing precisely the study questions and recommending how future research could be conducted.

CHAPTER 2: LITERATURE

Introduction

This chapter aims to identify relevant elements of farmer learning as it regards to water productivity and profitability in SIS. To accomplish this, eight topical issues on farmer learning were performed. The review concerned adoption of technology and its influence on household welfare starting with an African perspective premised on the fact that accepting improved technologies has a progressive and substantial influence on the welfare of smallholder farmers' households. Essentially, it contributes to enhanced food security and increases the revenues of adopters. It was then followed by discussion on smallholder farmers' circumstances and social learning, Technology use and its impact on household food security and poverty. This is followed by discussions on institutional and organisational characteristics, soil and water resources management, improvement of water use efficiency, policy formulation for irrigation development, theoretical and conceptual framework and knowledge gaps. This literature analysis converses published information about relevance of farmer learning in irrigated farming and reviewed academic sources related to the research questions formulated. The summary indicates the final discussion of the chapter.

Enhancing Smallholder Farmer Performance in Irrigation Facilities

A key to supporting and encouraging agricultural productivity of farmers in irrigation facilities is to provide a conducive environment for learning and facilitating access to reasonable and efficient technologies (Mansour et al., 2022). Increasing demands for food supply have influenced farmers to learn modern methods of farming as well as agriculture patterns globally. Moreover, varying human life styles, unprecedented human population increasing and urbanisation have directly affected crop production systems. Muluneh (2021) recognised that CC is swiftly occurring because of human activities that are negatively affecting the natural ecosystems. It sensitively modifies biodiversity and crop production thereby influencing food security and poverty levels,

The financial value of strategic plans and the shortage of water resources for both rain-fed and irrigated agriculture have prompted by smallholder farmers, extension delivery staff and agriculture researchers to discover modern methods to overcome the food crises that are happening at a very fast rate in the 21st Century (Touch et al., 2024). Whereas CC is defined as climate variation in an area due to anthropogenic and natural conditions, for example ozone layer depletion and greenhouse effects (Kotir, 2011). These environmental conditions may be due to the factors, for example, fluctuations in solar emission, long-term variations in the earth's orbital natural progressions, and also human forces on the earth's planet. Accordingly, the past century experienced the toughest warming trend with average temperatures rising by about 0.6° C (W. Huang et al., 2018). Nonetheless, it is projected that future temperature rises are expected to surpass this with estimated rises of between 0.1 and 2° C per decade (Bitz et al., 2011; Dullinger et al., 2004; Huang et al., 2018) Thus far, numerous technologies and efficient approaches have been and are being implemented in the agriculture sector. Still, literature shows that there is a great need to develop and/or advance the available technologies to circumvent the food insecurity challenges and demand-supply gap by enhancing production efficiency. Therefore, the question of whether the scientific discoveries are able to sustainably, successfully and efficiently feed everyone at global, regional and local level by 2050" is the key anxiety concerning the future of food security.

It is well accepted that smallholder farmers play a key role in food production worldwide, producing nearly 70–80 percent of food (FAO, 2021; Ricciardi et al., 2018). They are subject to various challenges and difficulties that impinge on crop productivity, profitability and ultimately their livelihoods. Environmental degradation, for example, soil erosion, loss of fertility and water insufficiency, pose weighty limitations on agricultural production, deterring smallholders' capacity to meet the increasing food demand (Carrijo et al., 2017; Rosegrant et al. 2024). Furthermore, smallholder farmers are experiencing intensifying climatic stresses, namely: protracted droughts, floods, erratic rainfall, including rising temperatures and increased pests and diseases incidences (Osumanu, 2022). It has been known that socioeconomic issues further complicate farmers' challenges particularly poverty, labour shortages, increased farm input costs, and miserable crop prices (Touch et al., 2024).

Farmer Learning and Behaviour Change

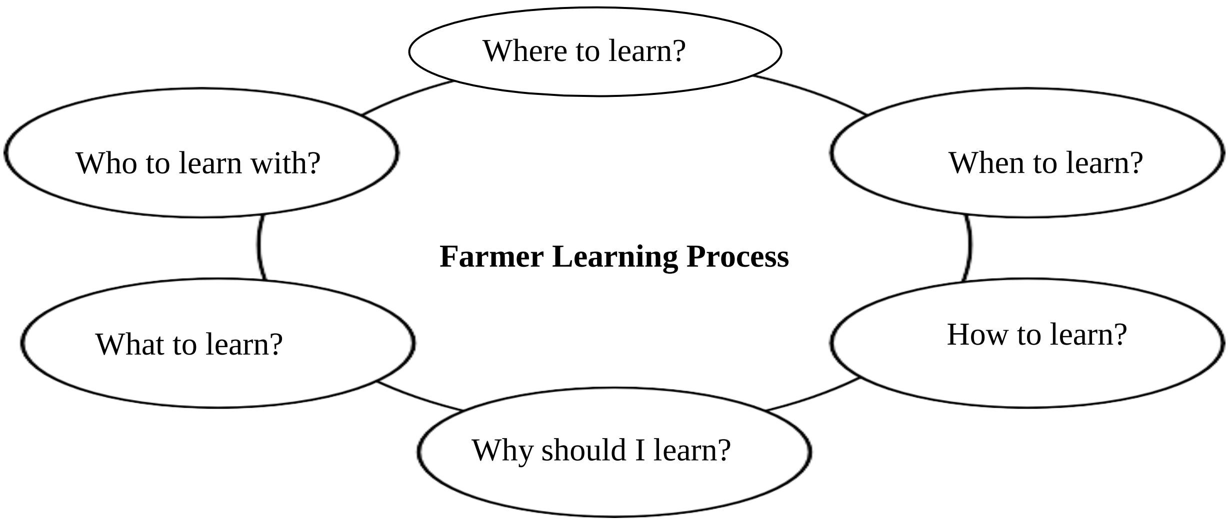
Learning can be referred to an instructive and enlightening approach that accentuates developing skills and competencies like critical thinking, ingenuity, inventiveness, teamwork, and interaction, these can enable farmers to circumnavigate a fast-changing world by dynamically engaging with others to obtain requisite information, utilising technology, and adapting to complicated challenges and problems, rather than exclusively remembering facts (Dhillon & Moncur, 2023). Fundamentally, it prioritizes soft expertise and competencies along with traditional knowledge preparing farmers for the rapid changing world due to climate change and weather variability. The central aim of this section is to look at the pertinent issues regarding farmer learning and discuss the social and behavioural-change opportunities and impediments that can influence farmers to accept and utilise modern irrigated farming practices that may raise water use efficiency and reduce nutrient leaching from the soil. Three essential queries that incited this enquiry are presented below:

The researcher posed the first question as. “What social or behavioural prospects or hindrances can increase or reduce the prospective increment of water use efficiencies by smallholder farmers using existing or user-friendly technologies and practices in small-scale irrigation schemes?” The second question was, “How can social or behavioural changes or hurdles amplify or decrease water efficiencies if existing and old approaches or adaptable tools and practices used in smallholder irrigation schemes are solved or addressed?” The last question was. “What strategies, farming techniques, tools, methods, or tactics can best resolve or tackle likely farmers' communal or behavioural hitches to exploit water use efficiencies using prevalent or feasible expertise and practices in smallholder irrigation schemes?’

The works by Roux et al. (2017) provide a similar alignment with the purpose of this study as it centres on shared farmer learning within irrigated farming, particularly on three characteristics that could otherwise guide other researchers in planning and facilitating learning, namely: “Whom to learn with?” “What subjects to learn about?” and “What method of learning?” The determination to knowledge generation and share information with other farmers (why should I learn?) is linked to the change of “as usual” doing things to the applicability of acquired knowledge in agriculture (Barbier and Elzen, 2012). This knowledge generation and acquisition can take different forms, but two general resolves are mostly pertinent i.e. knowledge to generate and improve policy approaches and choices, and considered as two opposing poles in a gradient that mirror a worldview approach (Alosaimi, 2016) against an inner-scientific approach to farming learning efforts linked with local or context-specific knowledge vs. generalized knowledge (Beck, 2019). Immersive learning which is appropriate for smallholder farmers appears to promote increased performance in farming knowledge particularly in water application (Beck, 2019). Immersive learning is observed training practices that use practical reality to create real-world consequences and guide individuals in a safe and engaging demonstrative learning environment. The researcher's main analytical learning framework is structured around six dimensions of the farmer learning process as depicted in Figure 2.3.

Figure 2.3

An analytical framework to assess the learning process in irrigated farming systems.



Adapted from Roux et al. (2017).

Adopting Mascarenhas et al. (2021) framework that demonstrates the stipulation through which individual learning undergoes, it indicates the crucial view that explores the following: the drive or essence or reasons for learning "(Why should I learn?)", what is to be learned "(What to learn?)", what players need to be involved "(Who to learn with?)", where to learn "(Which place to learn from?)", the scheduling of the various steps in the learning process "(When to learn?)", and the approaches to be employed "(How to learn?)". This framework can successfully be employed to plan a crucial and successful farmer learning. However, Mascarenhas et al. (2021) observed that the different appraisal topics in the structure do not inevitably follow a specific sequence.

This section of the literature review was tackled by considering and going through information concerning behaviour concepts, learning styles and decision-making processes of farmers, particularly relating to weather variability, climate change and water scarcity in rainfed and irrigated agriculture generally and smallholder irrigation schemes. A *literature review is* commonly conducted to *hunt, look for* and *evaluate existing evidence and data* on *a specific theme, topic,* subject or speciality. The literature review essentially *traverses* the *state*-of-the-*art* about new developments in agricultural science regarding prevalent shared challenges and problems (C. Hart, 2018). It is conducted to identify vital changes in approach or core beliefs that may enhance changing water resources management, an indispensable factor in agricultural production and viability essentially in emerging nations (Kirui and von Braun, 2018; Pék et al., 2019).

Human Behavioural Patterns Irrigated Farming

Numerous concepts recount human behaviours based on actions and how their performances can be modified or improved for the advantage of both the community and the environment. From the literature analysis done and official papers accessed, a key piece of information that emerged is that no single behavioural principle can argue for and fit every identified human conduct to realise a required behavioural change (Kwasnicka et al., 2016). Irrigated farming is the major sector that consumes gigantic water resources such that smallholder farmers are key participants who should take a leading role in water conservation. One of the crucial factors for food uncertainty that is challenging the agricultural sector is the lack of water resources. Most developing nations have provided training programmes for farmers to change their agricultural arrangements, produce lucrative crops and generate jobs. While the governments support the farming of valuable crops and promise their buying, attempts have been made to promulgate environmental policies that are intended to conserve water resources. The consideration of investigators and policy-makers for the implementation of water-saving rules has been acknowledged widely. In this investigation, the planned behaviour theory was used among others to ascertain the driving issues, which encouraged farmers to implement water-saving policies (Ajzen, 1991). For farmers to be attracted to join the water-conservation programme, crafting an optimistic attitude concerning involvement is vital.

Mature learning ideas offer opinions on how mature novices learn and can help others how advantageous new technologies can be if accepted and adopted in their agricultural activities. Additionally, how important they can be to the requirements of the learners they are to serve. There is no distinct learning model that can be useful to meet adults' state of affairs. Previous literature has influenced the emergence of a variety of models, conventional norms and tenets, and accounts that constitute the mature learning knowledge groundwork (Polly et al., 2017). When considering existing learning theories, it is imperative to reflect on the sociocultural views and the functions that culture, interaction, and collaboration have on farmers' quality and responsive learning.

Vygotsky's versions and some other sociocultural scholars' work have backed assorted crow's nests and a range of novel techniques for learning (Cherry, 2018; Vygotsky, 1978). Sociocultural concepts and related styles are generally acknowledged and established in psychology and education disciplines due to their causal concept that learning and belief are coupled. The sociocultural model is also becoming steadily influential in the instructional learning arena. Nevertheless, it is an evolving idea that guises the key accounts that humanity makes to a specific development, this idea emphasises the interface between concerned people vis-a-vis farmers and the culture in which they reside. Besides, it advocates that learning is a collective process. People need to interact with each other to communicate and share ideas that impinge on their social progress. Little et al. (2016, p. 911) claimed that face-to-face interaction is by far a more socially effective process than is mostly recognised.

Farmer Learning

The initial task in this section is to define learning. What is learning? Briefly, learning is a modification or conversion in one's behaviour that can be alleged, achieved, or restrained and contains the accomplishment of understanding, proficiencies, know-how and beliefs that are connected with an experience. At present, many people prefer and incline exclusively toward the intellectual view of learning. Inevitably, it indicates that the behaviour adjustment being detected has been modified because of the issues or events performed within the environment s/he executes and does his/her undertakings. This is essentially like that because it evaluates human beings as dynamic constituents within their advancement, expansion, improvement and environment. It is like that because some people learn differently due to some conditions surrounding them (Darling-Hammond et al., 2020). For instance, most mature people learn if they are encouraged by certain issues that challenge or create problems for them to make decisions that entail clear understanding or skill. As such, mature learners plan their learning processes. However, in some circumstances and instances, mature people search for help from peers, friends, co-workers, family colleagues, and fellow citizens. Professional support makes up only a lesser part of the resources used.

From the systems perspective learning can be described as any process that adjusts a system to expand, more or less irrevocably with its subsequent performance of the same mission or of responsibilities drawn from the same targeted group (Midgley and Lindhult 2021). What is of value to smallholder irrigators is that club establishment on schemes is a crucial strategy for farmer learning and can be very valuable, especially if other farmers in the club intend to change their status and gain similar knowledge and competency as others. In most situations, awareness and capacity are usually found within the same grouping, however, as the only unknown thing. It is well recognised that a club can offer and deliver inspiring and emotional values regarding urge, awareness, creativeness, initiative and a sense of shared achievement. A vital characteristic of gaining and accepting factors that are drivers of behaviour transformation is essentially how to include them in activities that can change someone's behaviour.

An opulent history of research findings freely accessible about the encounters of farmers has emerged from a need to inspire farmers' attitudes toward the proper use of water impetuses and apprehensions that take on concerns of ecosystem management and safeguarding practices. 5 focus on food security, rural development and environmental protection, is the engine in the accomplishment of the set targets. According to Myers et al. (2017), the agrarian account has explained repetitively vanquished restrictions and attributed the realised greater food production because of the areal expansion of cultivated land and intensification of farming through the adoption of modern and innovative agricultural methods and farming practices, for example, smallholder irrigation. FAO (2017) imagined a world that is capable of emancipating itself from food shortage but has people who are healthy and where malnutrition is non-existent and food security is certain. The agricultural sector supports greatly improving the living standards of rural people, expressly the poorest in society, in a cautiously, communally, economically and environmentally viable manner.

The significance of learning in irrigated farming is that it provides new knowledge and information to farmers and provides space for their growth through many interventions such as improvement of water resources use, increasing water use efficiency and also enhancing the livelihoods through agriculture advancement and modernisation as a vehicle for pro-poor economic development (Qwabe et al., 2022). However, it has been observed about the inconspicuousness of agricultural extension delivery staff in publics where helpless groups need their services the most.

Among the explanations behind active participation absence among extension delivery service staff can be ascribed to self-efficacy that is caused by several reasons, for instance, values and attitudes of an individual, lack of motivation, assertiveness, and failure to determine good problem-solving skills according to (Igbor, 2019). This is an essential predicament that need to be swiftly dealt with and conceivable resolutions could be found through peripheral interventions. Besides, self-efficacy absence can influence person's performance that can ultimately work against the aims of farmer learning centred around improving the quality of life as it is strongly associated with a personal's sensation regarding their beliefs and capabilities, which subsequently affects behaviour (Hardy III, 2014). It is also important to accept that there are many issues that contribute to the invisibility of extension staff in communities particularly in irrigated farming systems. Some of these issues can be attributed to internal challenges, for instance, from institutions that are responsible for extension delivery services. The reasons that are usually provided include insufficient resources for extension experts, newly graduated join non-government organisation for greener pastures and multidimensional work requirements (Agwu et al., 2023).

Smallholder Farmers' Circumstances and Learning

Agricultural production in Malawi transcends many generations. However, unprecedented changes are happening globally, regionally as well as locally which are challenging the ability of subsistence farmers to sustain agricultural production that was easily achieved when there was less pressure on land resources due to the low human population (FAO, 2017). This world is based upon uplifting the standards of living of the underprivileged to attain a decent livelihood. A livelihood consists of capabilities, assets, and activities required for a means of living according. Smallholder farmers' prosperity plays a very vital role in technology acceptance and adoption. It is therefore presumed that cheap technologies can be easily accepted and adopted by this category of farmers. Many authors have investigated technology adoption in agriculture by measuring farmers' wealth through factors such as age, landholding sizes, gender, education, and leadership (Gebre et al., 2019; Meijer et al., 2015, Mwangi and Kariuki, 2015). Through learning, smallholder farmers can harness the ability to bounce back from displeasures encountered and sustain an optimistic attitude, even when things look unpromising.

Since efforts are geared towards sustainable explanations that tackle multiple issues will likely benefit smallholder farmers from a convergence of scientific knowledge and innovations that make use of information from social learning and cognitive sciences (Rosário et al., 2022). Social learning based on farmers' social platforms can, therefore, improve material exchange and interaction among people, thereby assisting in reducing the ambiguity involved when applying modern agricultural innovations (Li et al., 2018). The works by Roux et al. (2017) provide a similar alignment with the purpose of this study as it centres on shared farmer learning within irrigated farming, particularly on three characteristics that could otherwise guide other researchers in planning and facilitating learning, namely: "Whom to learn with?" "What subjects to learn about?" and "What method of learning?"

Conducive Environment for Farmer Learning

Due to rapid global transformation activated by CC, people's behaviour is changing so dramatically that the roles of instruction and learning are emerging across radical changes. This transformation is experiencing varying trends of instruction in the 21st century in which people's needs and demands to succeed and thrive in the global workplace require a conducive environment for learning new ideas and practices (Thornhill-Miller et al., 2023).

A positive and conducive learning environment is key to behavioural transformation because it significantly impacts a farmer's ability to participate, retain information, and develop a positive attitude towards learning. By interacting with other farmers, it can lead to improving farming practices and better farming outcomes through promotion of a sense of care, comfort, and impetus to engage proactively in the learning process (Jepsen et al., 2022; Molina et al., 2021). Factors, like for example, physical space, social interactions, and facilitator support, all contribute to the inclusive excellence of the learning environment. Farmer learning and training conducted for the right target, at the right time, in the right way, and at the right place is important for improving irrigated farming methods and techniques that boost crop production efficiency and revenue, ultimately enhancing household livelihoods. The needs assessment of beneficiary farmers should be at the centre and focus on the local context that may build on experience, farmer knowledge as well as on prevailing circumstances

Bearing in mind the leading environmental conditions in which food security is swiftly varying globally swayed by climate change and variability (Vitsitsi, 2019), agrarian activities face a tripartite challenge. One, agrarian production ought to be amended to balance a growing demand for food driven by unprecedented population growth globally. Two, the agricultural sector is considered in many emerging nations as a key to job creation that can improve household incomes thereby significantly influencing poverty eradication and raising rural economic growth. Last but not least, the agricultural sector plays a foremost function in the practical management of natural resources and the tuning to, and equability of climate variability that is crucially affecting the occupations of many people, exclusively the ones most at risk.

Supporting crop production and efficiency, while preserving and augmenting natural resources management, for example, protecting water resources, are indispensable ingredients for smallholder farmers to intensify and promote food crop yields on a more sustainable basis (Paris, 2010). The role played by smallholder farmers in increasing crop yield sustainably cannot be overemphasised. Smallholder farmers are the hub of any transformation process that implicates natural resources. They are supposed to be inspired, invigorated, exhilarated and guided, through fitting incentives and correct governance methods, to shield and safeguard natural ecosystems as well as moderate the undesirable effects farming activities can bring to the environment (Ranaivoson et al., 2017; Lalani et al., 2016). Green farming vis-à-vis irrigated farming is a strategy that is reflected and perceived as an integral part of sustainable economic development.

Almost all countries in Sub-Saharan Africa generally and Malawi unambiguously have made fantastic and remarkable progress in increasing food security at the smallholder farmers' level in recent years, largely because of irrigation expansion (Béné et al., 2015). Nonetheless, rural poverty remains ubiquitous and economic development has been too disappointing to be translated into social gains. The irrigated agricultural sector, on the other hand, has been experiencing several challenges and problems that have hampered its fitness to meaningfully back livelihoods and eradicate poverty at both the household and national levels (Fincham, 2020; Poverty, 2017). These challenges and problems can, by some means, be thought as complex because of the lack of modest practical knowledge and necessary tools for less educated as well as illiterate smallholder farmers who are in the majority in the least developing countries in which political and institutional factors are decisive drivers of change in industrial as well as agricultural sectors. It is, therefore, important to understand these dynamics through scientifically planned investigations and how their findings can shape irrigation programmes, practices and performances to chart acceptable conduits for future irrigation sector development (Gallagher et al., 2016; FAO and WWC, 2015).

Learning in Smallholder Agriculture

Many developing countries to boost production and productivity in their agricultural sector make use of extension service delivery which is well acknowledged. Access to information and skill within the prevailing epistemic system is unevenly distributed among smallholder farmers in

Africa generally and Malawi specifically (Danso-Abbeam et al., 2018; FAO, 2017; Milanzi, 2017). The concept of epistemic oppression refers to persistent epistemic segregation that hampers contribution to knowledge production. This follows from a supposition that epistemic forms of coercion and subjugation are generally reducible to social forms of oppression such that the systemic emphasis on a certain group of farmers may work to the detriment of the rest of the farmers. This oppression can be done away with thorough farmer learning.

It is currently observed that many farmers opt for local-level learning for knowledge acquisition and/or contribution to the production of new knowledge. For such farmers, social interaction and learning are survival mechanisms against segregation in knowledge and technology transfer. Current agricultural extension service delivery in Malawi is based on so-called lead farmers who have shown to be productive and conversant with what is happening and are part of the local community. They are known and can be entrusted with the task of technology demonstration and dissemination.

According to Ragasa (2019), lead farmers have been part of the extension service delivery model since independence in Malawi. In the past, the lead farmer approach had been condemned for choosing particularly richer and progressive farmers whose harvests are low and had no development effect. Due to a shortage of frontline staff, the lead farmer approach has been revived that has contributed to a substantial number of farmer trainers present at the community level who also have closer ties to social platforms, interested volunteers, and are chosen and voted by participatory processes within the community (Nankhuni, 2017). Moreover, they must have perfect attitudes and behaviours. What is more important is that farmer learning is based on social learning theory that suggests learning to be a cognitive process that happens within the social background. The learning process can occur simply through watching, reflection or direct instruction by someone. Additionally, by observing the behaviour of others, learning can also occur. It is recognised that social learning theory integrates interactive and mental theories of learning to provide a full model that accounts for comprehensive learning experiences that ensue in the world.

The success of the extension service delivery system in the agricultural sector has been questioned on the grounds of apparent failures to influence desired changes and improvements in output and/or social impacts. Subsequently, approaches have shifted the focus of knowledge production and learning, towards more social interaction and sharing perspectives in which the agency and practices of the smallholder farmer as a learner are more clearly known and familiar (Jones et al., 2017). Since efforts are geared towards sustainable explanations that tackle multiple issues will likely benefit smallholder farmers from a convergence of scientific knowledge and innovations that make use of information from social learning and cognitive sciences. Social learning based on farmers' social platforms can, therefore, improve material exchange and interaction among people, thereby assisting in reducing the ambiguity involved when applying modern agricultural innovations (Li et al., 2018).

Per se, the role of farmer learning in the use and extension of sustainable technologies in the agricultural sector is currently attracting increased attention. It is acknowledged in the literature that approaches to farmer learning and acquisition of knowledge are influenced by policy processes that integrate agriculture more closely within a broader context of natural resource management and widely based rural development. The policy processes and investigations underscore the farmers' contexts within wide systems of knowledge, identify the socially facilitated generation and use of agricultural knowledge, and shift research interest towards processes that respond, to some extent, to the top-down and linear models of learning, production and acquisition of knowledge (Šūmane et al., 2018). Farmers generally value local experiential learning and knowledge acquisition as they understand by having hands-on experience, placing special value on what they practice and local situational relevance. Experiential learning is a participatory learning process whereby learners vis-à-vis farmers learn by doing and by reflecting on their experiences.

Social Learning through Network Platforms

So that smallholder farmers improve their livelihoods there is an absolute need to adopt a technology that can solve the challenges they experience in farming. This is key to the farming systems revolution during any economic and agricultural development process. Salazar and Rand (2016) focused on challenges encountered by smallholder farmers as they decided to adopt a potentially lucrative technology for irrigation associated with production risks. Besides, production threat is frequently related to the adoption of conventional irrigation, and this threat more often challenges a change to more current irrigation technologies. Any change is associated with doing things differently from the old to the new way its pathway is learning through either formal or informal pathways (Passarelli & Kolb, 2011).

It is noted that investment in irrigation is dependent precisely on the degree of farmer participation in training. Participation avails the participant opportunities to understand the internal technological capability that can be acquired through practice as demonstrated on how to use the technology. **I**ndividual heterogeneities exist that define interest in acquiring new farming practices associated with the new technology. In recent times, farmers have been informed about the presence of new farming technologies and their effective use through social networking for instance extension services from either private or public extension. Taylor and Bhasme, (2018) claimed that model farmers are a common example of many emerging global agricultural extension systems within which they show current farming methods and technologies to local communities. Pratiwi and Suzuki (2017) argued that agricultural information can be transmitted through social interactions within farmers' localities determining information-gathering abilities, a process of learning recognised as experiential learning.

Experiential learning in agriculture refers to the learning process that occurs through social interactions between a farmer and other individuals in his/her social network. Such learning has been acknowledged as influencing decisions at different stages of farming like a choice of crops and inputs, irrigation system or any other form of a farming system. It is through farmer learning sequences which the adoption of technology can be successfully achieved. Ngulube et al. (2015) constructed a theoretical framework around such sequential patterns of social learning that inform the research process. Understanding that technology information flows sequentially from one farmer to another is important as adoption cannot take place instantaneously. There is a typical time lag between farmers' perception of the technology, how it can be used to circumvent the challenges faced and how much return on investment is realised. Based on Experiential Learning Theory (ELT) learning acquired by individual farmers emphasises learning through experience also known as "learning by doing".

Herbert et al. (2015) examined the influence of farmer learning on the adoption lag of agricultural technologies and farm performance. They found out that long periods of participating in farmer groups reduce adoption lag and much more so if merged with sustainable extension service delivery. The implication is that the farmer groups function as important learning machinery for improving crop production and productivity. Dooley (2020) claimed that farmer discussion groups are a collaborative mechanism through which farmers can engage and learn from and with their peers. However, Huang and Karimanzira (2018) earlier presented evidence on farmers' decisions to use a new type of fertiliser after soil testing. Fertiliser approval services can help farmers attain ecological and economic sustainability by helping farmers appreciate their soil conditions so that they can be able to reduce agrochemical application habits. By using the right amount of fertiliser applied to soils they can minimise input costs, and achieve higher crop yields. For irrigated farming, nutrients can remain within the soil rooting zone such that adequate water can be applied with the knowledge being gained through farmer learning.

Makonnen et al. (2018) found an encouraging relationship between linkages and the adoption of row-planting as well as crop productivity in male and female groupings. However, the evidence for an inverse U-shaped rapport of social interaction, that is, between the adopters in the groupings and the acceptance of row-planting, was strongest for female groupings. This work established positive interactions between the number of adopters and the individual farmers' decision to adopt. It cannot be denied that human beings by nature are social creatures that require to be understood, for example, human infants are born unable to transport or care for themselves but need support from older ones so is the same with training (Kagan & Kauerz, 2015). There must be others who are more knowledgeable to impart current knowledge to those who do not know. Thus, their survival depends on another human's efforts.

The world around us is developing through the filter of other people's experiences such that those who do want to change their status can emulate what others are doing. However, as Tithi (2015) suggested people's connections to others are key to not only survival but also the happiness and success of livelihoods. This current state of affairs, therefore, encourages people to participate and interact with others. Food insecurity and poverty are the factors that pinpoint what people can do to change their status. There is increasing consciousness and recognition in the farming community that crop productivity outcomes and disparities, more frequently than not, are inspired by social determinants. The determinants in rainfed and irrigated farming include physical, economic, social, cultural and/or other circumstances where people reside, farm, and learn that influence their welfare. It is well known that poverty and food insecurity are among the social determinants of livelihood, which are linked to some of the most thoughtful and relevant challenges and problems for a developing nation (Dury et al., 2019; Hartline-Grafton and Dean, 2017; Rembold et al., 2019; Van Der Vegt et al., 2015). Mindset change is a universal topic within irrigated agriculture at the moment essential due to events of climate change and variability.

Participating in a social group supplements conversation, contacts, trust and teamwork. Hence, connection to a group with comparable characteristics could strengthen innovation acceptance and adoption. Access to extension services is assumed to increase technology adoption after the acquisition of knowledge and understanding of technology (De Janvry et al., 2017). Participation in farmer field schools has shown that knowledge is required of its influence on the daily activities of participants beyond the benefits of farming. Mehmood et al. (2020) considered people's transformative role and the places in which they dwell and occupy by performing several activities for their benefit. Farmer field schools under the lens of transformative learning theory are such facilities that should be appreciated through the effect that participatory and group-based learning can have on participants' lives.

According to Bista (2018), participation in farmer learning groups helps the accumulation of human, social and financial capital. The capital gained contributed to mental, social, economic and political confidence such that these attributes should be considered in isolation but demonstrated the organised nature of various forms of capital growth. Furthermore, the results disclosed that response loops prevail between the empowerment suggesting that progress in one capital form is not sufficient to ensure farmers' confidence across the four dimensions unless at least two forms of capital are already present. Presenting this in another way, the findings revealed important results that knowledge acquisition can only be possible if one learns of the existence of new knowledge as well as the effective use of technology. Smallholder farmers will only adopt new technology if they are aware of or have heard about it through social networking or from other farmers. Thus, the exchange of information between farmers is one of the most pertinent factors in agriculture. According to Ingram et al. (2018), smallholder farmers can learn through demonstration farms in the form of smallholder farmers' information access channels.

Social structure is one of the influential factors that determine whether an individual can or cannot access innovation. Roth (2015) explained that to create awareness of the innovations to affect, structural rigidities within social systems must be overcome although there is unusual disagreement in current discourses concerning innovation. The term, innovation is applied to nearly every type of spectacle. For instance, new inventions, methods, services, styles, practices, and even the market access or social diffusion of innovations, are termed innovations. Besides, it is common simply to use the concept as an overall metaphor for conversion in mindsets, groups, or entire societies so that people can learn new things (Edwards-Schachter et al., 2015). Status in a social system is also vital and influence's opinion on important issues. For example, individuals of higher status are assumed to be opinion leaders on topical matters for which they are known and are targeted by development agencies to participate in any effort that can bring change to communities. The assumption is that once these individuals accept and adopt a technology it will trickle down to other members in the social grouping thereby changing the social status and wellbeing of the community.

Farmer Learning for Technology Adoption

Literature abounds on determinants of technology adoption in the agricultural sector generally and irrigated farming particularly. Smallholder farmers usually experience tough decisions about whether and how to accept and adopt a new technology that is being promoted against the one they are accustomed to. The question that is asked and needs answers is: "How do smallholder farmers learn about a promising technological innovation that can help meet their household expectations regarding crop production? Most of the answers from research studies show that, because of farmers' habits, traditions, and convenience factors, information access channels generally include interpersonal interaction, radio, television, and other mass media (Chen & Lu, 2020).

There are a variety of information sources from where new agricultural technology can be known. In developing countries, smallholder farmers may learn from extension agents who are front-line experts to provide information about an innovation that has been tested and is proving to be excellent in improving productivity. Dhehibi et al. (2020) argued that the key challenge for policy decision-makers to increase production and productivity in the agricultural sector is to encourage and improve the acceptance rate of innovative related technologies so that farmers can manage and protect natural resources. Besides, information can be acquired from other farmers who have tried or been trying an innovation. Furthermore, a technical message may be obtained and disseminated by extension agents, electronic media, etc. When many people and/or farmers experience similar challenges in crop production, a learning process emerges to solve that challenge and becomes a social learning activity.

The global environment is changing rapidly characterised by increased demands on the part of the agricultural industry because of erratic rainfall in recent times. Thus, the key objective of smallholder farmers or estates is to be successful in crop production and household welfare. This means that farmers must quickly respond to the changing conditions by adapting themselves to the innovations to keep pace with the increasing population and climate variability. Climate change and variability are a key challenge, particularly in arid and semi-arid areas where peoples' livelihoods are largely reliant on subsistence rainfed crop production.

Joshua et al. (2016) suggested that rural communities are the most susceptible to the unpleasant effects of climate change and variability due to their low illiteracy and adaptive capacity. Adaptive capacity is the ability or capacity of people to modify a system to their advantage or change its characteristics to cope better with the prevailing or anticipated external stresses and conditions. Adaptation to climate change and variability is the alteration of a natural or human system to moderate the influences of climate vagaries, take advantage of new changes, or cope with the outcomes (Ojha et al., 2016). It may be noted that adaptation happens in response to actual or expected effects of climate variability that moderate the destruction or abuse of valuable prospects. Moreover, farmers are conditioned by the dynamic interaction between the characteristics of the innovation itself and the array of conditions and circumstances under which they experience it. Consequently, farmers need to learn from experts or others to improve their standard level of living.

Currently, much of the social or farmer learning process has been widely documented and advocated (Petrics et al., 2015). Previously, the top-down approach was the order of disseminating information and messages in agriculture. This proved to be cumbersome and difficult since farmers' views were not taken on board. Researchers popularly noted and discovered that when farmers are included there are momentous benefits of overcoming perceived failures of top-down, the one-size-fits-all syndrome. In a pursuit to understand how participants in the learning process have gained, mostly how they make sense of their experience of participatory extension, researchers in technology transfer have explored ways in which experiential learning theories, especially transformative learning theory, can inform farmer participation to overcome poverty and food insecurity (Gassner et al., 2019). The availability of new technology is not final, but it has to be promoted based on the desire that propels smallholder farmers to improve their situations. Thus, there must be a platform where the technology can be made available for users to appreciate and try to use it. A technology platform comprises a group of individuals with different backgrounds and interests who meet together to diagnose problems and challenges, classify opportunities and find ways to circumvent them. Once farmers agree on their common issues and conditions, they are ready to accept any corrective measures and support.

A condition in this respect is a prerequisite or a characteristic that must be present if something else is to happen. The acceptance of the conditions available makes the technology trickle and spread among smallholder farmers a process known as diffusion regardless of the level of education. Diffusion results from a sequence of decisions that have been carefully studied so that new technology can be used. According to Hall and Khan (2003), an appreciation of factors persuading the selection of innovations is necessary both for researchers studying the determinants of growth and the producers and extension agents promoting such technologies. While there are many classes for grouping factors of innovation adoption, there is no clear distinctive feature between variables in each classification. Thus, understanding variable taxonomy can play a key role in research methodology, providing a structured outline to categorise and examine diverse kinds of variables. Understanding this taxonomy is indispensable for researchers as it aims to derive correct deductions from studies. Besides, it approves detecting relationships between variables, contributing to the inclusive effectiveness of their research design.

Issues Influencing Irrigation System Selection

Several factors affect irrigation system selection based on who is doing what. Topography looks at the slope of the ground about how uneven or levelled the ground surface is so that an irrigation system can be selected accordingly. This action is within the engineering discipline since the topographic survey is the most commonly exercised survey work in irrigation projects carried out mostly by engineers (Mohammed, 2019). Engineers base irrigation system selection on land surface slopes. They consider three-dimensional observations and employ the method of plane surveying and other distinctive techniques to establish both horizontal and vertical control. For instance, if the surface slope is between 0.4 and 8 percent, corrugation irrigation is appropriate.

However, if the ground slope is more than 8 percent, then the sprinkler method is more suitable as soil depth determines the method. Likewise, smoothed surface flow, border, as well as furrow irrigation methods, may be supported by both the engineers and farmers themselves (Valipour et al.,2015). Despite level differences, the soil structure and composition may influence the selection of irrigation methods. Deep soils with medium and fast permeability are suitable for the corrugated method of irrigation. However, the rate of water seepage through soil depends on its composition (N. G. Patil & Singh, 2016).

Besides, the means of irrigation, crop types, economic labour, and texture of soils as significant factors for irrigation system choice, and the climate has been noted to be a salient ingredient in irrigation system selection (Shahdany & Roozbahani, 2016). Surface irrigation methods have been suggested as directly affected by climate. Whereas, a sprinkler irrigation system is most appropriate for areas with a drier climate. Thus, dryness, humidity, and airspeed influence irrigation method selection (García et al., 2020; Nikolaou et al., 2020). It can be argued that the prevailing irrigated farming patterns do not essentially exhibit the suitability of land nor smallholder farmers' reflective knowledge of environmental needs that may effectively sustain a crop on unsuitable land. Currently, the growing of crops is based on socio-personal or economic reasons to avert hunger and at least income for household requirements (Kanianska, 2016). But smallholder farmers accept a new technology if it is cheap, needs little maintenance and provides essential information for crop growth and maximum water use efficiency.

Learning Approaches and the Experiential Learning Cycle

Developing sustainable pathways through which food insecurity and poverty eradication are indispensable, the behavioural transformation of farmers is perceived as a must. This involves people, particularly smallholder farmers participating and taking a leading role in the investigation to change their circumstances as researchers and scientists alike may have conceptualised notional constructs of how they may behave in the investigation. The formulated constructs support in determining and identifying effects that may either affect and/or maintain the existing behaviours and attitudes of participating smallholder farmers. This course of action can take place consistent with steps that have been identified and defined according to times rooted in the experiential learning cycle through the problem-solving procedure. As stated, the experience exhibited by the researcher or investigator is the key. Experiential learning can be stated as a learning process through which learning and experience are as expected acquired by doing activities demonstrated and imitated. Experiential learning primarily engages learners vis-à-vis smallholder farmers in an experience and then stimulates thinking about the experience gained in acquiring new knowledge, skills, attitudes or new ways of thinking (Eamer and Rodrigues, 2020; Grade, 2016). Several developing nations have followed agricultural extension delivery that is tiered where linear systems for technology awareness and transfer are utilised. Farmer learning is, however, associated with innovation that pursues an interactive process (van Mierlo & Beers, 2018).

Smallholder farming activities prompted by climate change due to water shortage conducted in irrigation schemes follow a community-connected process where farmers take the lead, particularly in water supply delivery and are commonly in constant contact with one another to discuss challenges being encountered. Different types of farmers who participate in irrigated farming activities for instance illiterate farmers who have never been to school or attended any type of education may not comprehend the reasons why water is scheduled. Some have been to school but due to some circumstances left school and only attended at least a primary education. Some have been to a secondary school and because of retirement, they are currently involved in irrigation. Some who have tertiary education participate in farming but do this to help their relatives, and others and/or have a stake in the irrigation schemes. In this respect, some farmers are novices or beginners while others are experienced experts who have or had occasion using the experiential learning method (Phuong et al., 2019). Community-coupled initiatives can signal a shift in focus from considering the natural locale of the experiential learning event that links individual smallholder farmers in a public arrangement that offers to deal with people as they interact to solve a common challenge and/or problem (Thomas et al., 2020). Farmer learning is, therefore, linked to the communal milieu that is real and its energy is perceived as the foundation of the knowledge and the necessary learning that can be derived from such an arrangement.

According to smallholder farming communities themselves, the learning environment should provide opportunities to share keenly to gain new facts that are linked to irrigation so that they can imitate the shared experiences they have acquired their values and apply what they have learned from using new technologies and processes followed during decisions and actions in different phases of their irrigated farming roles. As Mann (2016) argued, human thinking is presently considered a decisive ability indispensable for self-acting and understanding. Increasing and acquiring experiential learning evidence confirms copious advantages as essential aptitudes for farmers' self-examination, expands approval of reactions and feedback provided by their peers, and consents for the fusion of new and fundamental information, awareness and practice. So, the acquired new experience can fittingly change previous behaviour about irrigated farming practices (Parry et al., 2020; Mango et al., 2018; Kissawike, 2008).

To summarise this section the question to answer concerns what experiential learning is. Loosely expressed, experiential learning includes a locus to a cycle of knowledge acquisition that covers three important points. One, smallholder farmers participate and engage in community-linked learning skills, Two, the farmers deliberate and reflect on their experiences before and after the introduction of the new issues to derive the meanings from them, and three, to apply what they have learned in various aspects of their lives. It can be argued in the irrigated farming process that the extension approach of disseminating information about technologies to smallholder farmers to directly change their farming practices in most cases contradiction may be brought to the existing farming practices (Dhehibi et al., 2020; Jew et al., 2020). To improve sustainable agricultural production, harmonisation of message and evidence exchange between researchers, extension workers and farmers is imperative. Innovations with no farmer involvement are not sustainable. In addition, several types of innovations that may be advocated by researchers do not necessarily meet with approval of farmers as their knowledge is not taken on board during planning and greatly overlooked.

Farmer Perception of Learning

Many perspectives have been developed over the years to study the processes involved in farmer learning. Most learning ideas focus on the importance of the methods regarding learning where it is provided and takes place, as well as the environment in which the learning is being conducted. There are various ways in which learning can be provided both formally and informally. Those who implement learning activities have been charged with explaining principles of learning and direction into conditions for instructional materials and actions (Cordingley, 2015; Tait-McCutcheon and Drake, 2016).

In consequence, learning can be given as part of a social grouping in a classroom setup, meeting or field demonstration for farmer groups. It can also be given on a one-to-one basis for mentoring or tutoring plans as well as individual learning like in tertiary education. Besides, individuals learn in many different ways and at different times in their lives and under different circumstances (Philippi, 2016). Learning is intended to transform people's behaviours, however. Learning that takes place in smallholder irrigation schemes can be referred to as mutual learning, Mutual learning provides an opportunity for self-reflexivity that is key for knowledge production expressively in irrigated farming (Hazard et al., 2018). It is a salient process that influences the flexibility and supportability of social-ecological systems. There are contradictory views regarding adult learning as it is different from juvenile development practices and general learning methods, however. It is also recognised that all learning styles are relevant to both young and adult learning, with of course differences according to the use of the style based on the learning environment. But what is learning? Learning has been defined in several ways by several different philosophers, scientists and educational experts. While common agreement on any single definition is absent, several definitions use common elements. In this respect, learning can be defined as an enduring behaviour transformation, or the role to behave in a given manner that results from practice or other forms of experience (Darling-Hammond et al., 2020).

Jambo et al. (2019) claimed that farmers need to change their behaviour to successfully benefit from new technologies developed to improve agricultural production and productivity through an increase in water use efficiency. Social experts have underscored the importance of non-economic issues that elucidate human behaviour, for example, the enthusiasm and incentive to accept and adopt agricultural innovations. Appreciating human motivation patterns can improve the effective implementation of crop production. If farmers are experienced and freely implement farming practices in an environment where they feel linked to other farmers and society, dissemination and diffusion of farming practices and innovations become facetious (Mungai et al., 2016). Allowing farmers to freely select among the available set of sustainable intensification of smallholder farming practices can improve their livelihoods, by evading a disparity between farmers' context, requirements and existing farm management practices.

With climate change and variability, one wonders how food insecurity and poverty reduction can be achieved particularly for the resource-poor farmers in developing nations. While increased attention is being given to agricultural management concerning how water quality and quantity are being affected, smallholder farmers' perceptions may be different from the scheme's managerial point of view. Based on integrated water resource management that underscores stakeholder participation, several forms of knowledge and sustainable practices converge on farmers' behaviours. This is because a farmer is an important decision-maker who can influence when diffuse pollutants emerging from irrigated plots can find their way to the water environment which can be well managed by changing how these are disposed of from the plots (Glavan et al., 2019; Hargrove and Heyman, 2020). Considering the reasons for such decisions and behaviours is so important to adopt an integrated approach to adjusting agriculture's effect on water quality.

Farmer behaviour can be persuaded through using many institutional types of machinery like legal tools, pecuniary rewards, advice delivery and charitable collective actions. Certainly, information and provision of advice work in partnership with other institutional types of machinery, as a cross-cutting theme. Thus, a farmer's behavioural change concerning water resources management recognises the need for participation in learning new methods for farming to protect water resources and increase water use efficiency. Moreover, it can be argued that farmers' behaviour change can lead to increased profitability of households as less water will be used to produce high yields. This action will continue over time as it is more likely to become entrenched in social norms (Liu et al., 2018; Khapayi and Celliers, 2016). However, efforts to rouse farmers' active participation in learning require an understanding of their prevailing behaviours, and how information can help influence behavioural change. Managing common-pool resources like water commonly requires action on a collective scale that focuses attention both on an individual farmer and also group behaviour.

Farmers' Behaviours of Technology Adoption

An important challenge that researchers face in emerging countries is the speedy need to develop a sustainable farming system that can improve water resources use, and soil fertility, optimise land use and maintain long-term agricultural productivity at reduced costs. Due to changes in rainfall distribution and a high farming population, irrigated farming systems can no longer be practised efficiently and effectively. Extensive land use and inappropriate application of water in irrigation schemes have led to land degradation. According to Tuğrul (2019), people want food to live, and this is largely based on natural resources. But time is also needed to meet these limited natural resources whereby the human population has increased consumption demands, and for agriculture's renewal cycle. This cycle can be conventional, industrial and commercial, as well as sustainable. So, the question can be: “What is sustainable agriculture?” Sustainable agriculture is the way farmers try to increase crop productivity and boost the level of economic prosperity through the protection of all things, living spaces and natural resources (Tuğrul, 2019; Krall, 2015). To sustain crop productivity at the present level and possibly increase it, the use of fertilisers and increased water use efficiency is being introduced into irrigated farming systems. To encourage increased water, use efficiency and conserve fertiliser within the crop rooting zone, farmers in smallholder irrigation schemes are being encouraged to use simple soil water monitoring tools.

How new agricultural technologies are accepted and adopted has been investigated widely since the breakthrough of maize hybridisation in Iowa. The literature ascertains a huge number of factors that may be linked to the degree and rate of technological uptake in varied situations and farmers' circumstances (Fernie and Tohge, 2017; Hyde et al., 2018). They contain technology characteristics in terms of compatibility, visibility, divisibility, and resemblance as well as current technology; socio-economic characteristics of the household unit based on land tenure, sizes, the relative value of farming and labour situation; physical qualities of the landholding like land area, fragmentation and land quality; individual and mental attributes of key decision-maker within the household unit such as age, education, attitude to risk; and farmer's perception of future expectations based on climate change and variability (Vitsitsi, 2019). The relative effect of these issues varies between households and landholding sizes, and over time.

A challenge that has been observed in many of the studies carried out and, consequently, regarding diffusion models based thereon, can be acknowledged as ‘pro-innovation bias. The implicit assumption that all decision-making units vis-à-vis households make in a given context ultimately accept and adopt the innovation in question, which sometimes does not consider the users' views. Gatzweiler and von Braun (2016) argued that the majority of smallholder farmers in developing nations, particularly in Asia and Africa are affected by progressively intricate global and national environmental and economic transformations. As such, agricultural innovations and technology shifts are indispensable among the forces of change and the incorporation of innovations with services can, therefore, be simplified via institutions that are created to guide their dissemination. The inclusion of smallholder farmers' views is important as it provides utilisation sustainability of the innovation (FAO, 2016; Hatab et al., 2019; Jayne et al., 2017; Williams et al., 2018).

Efficacy of Farmer Learning and Behavioural Change

It has long been documented that, to appreciate smallholder farmers’ environmental behaviours and actions, reflection is needed on both interior issues and exterior conditions in which they operate. It is the chemistry of these distinctive factors that is crucial, and it may vary in different situations. This perception has influenced researchers to study the rapport between the will to adopt terms of farmers’ attitudes, principles, morals and norms towards environmental protection and profitability and the ability to adapt based on the economic circumstances of the farmer and compatibility with the farming system, external driver etc. A salient condition for sustainable irrigated farming can be based on the fact that a large number of farming households should be motivated to use a collective resource management philosophy that influences interaction among all manner of farmers. More recently there has been an increased interest in the value of farmer engagement with advice from extension staff and support systems in persuading farmers to behaviours that relate to sustainable agricultural practices (Mills et al., 2017).

Leisurely adoption of innovative technologies particularly by smallholder farmers in developing countries is of major concern to policy decision-makers, technology developers, and extension service delivery designers within the agricultural sector. Increasing a deeper understanding and appreciation of self-efficacy and learning play in farmers' decision-making processes may influence agricultural extension activities as argued by (Wilson et al., 2015). Determining and appreciating self-efficacy values and beliefs can also help smallholder farmers and agricultural frontline extension staff to make personal decisions that may benefit the economic development of the country.

Valuing smallholder farmers' environmental behaviours is a complex process. There is generally a compromise that farming systems are varied and that the situations and outcomes for decision-making concerning the environmental scenic view will differ greatly in space and time. Thus, smallholder farmers' preparedness and their ability to cooperate in achieving, for example, water resources management objectives cannot be abridged only to the location of consideration, the farmer attitudes or values, or to broader social and economic issues in an atomistic fashion. The atomistic fashion entails the composition of many simple parts typified by division into unconnected fragments.

Farmers have to deal with the complex interaction of agronomic, cultural, social and psychological factors to achieve their livelihoods mainly in developing countries. Each of these issues on their own cannot be of benefit but can play interlaced roles in national, regional, local and specific farmer's household contexts. These factors can influence an individual farmer's response to participating in environmental activities voluntarily (Kanianska, 2016). Tentatively, the rapport displayed by these factors has been studied concerning farmers as an agency, their structure and interaction in the context of simple soil water monitoring devices participation in which a farmer accepts that decision-makers have a complex set of goals related to many aspects of their life and focuses on motives, values and attitudes, and structure pays attention (Page and Petray, 2016).

Exclusively in the irrigated farming situation, linear, top-down delivery of information diffusion, whose achievement is hardly a secret. It sometimes fails to capture the systems complexity and processes. To be valuable, new knowledge and information should be place-context and culture-specific. It should mainly be harmonious with the local conditions, accuracies, challenges and problems rooted in particular social milieus and the local culture (Thomson et al., 2007). Thus, in irrigated farming facilities, the emphasis should divert from knowledge transmission and dissemination to knowledge and information co-production. The actors involved integrate their knowledge to amplify a mutual appreciation and understanding of the environment. Personal experiential knowledge and learning provides and lays the basis for the shared knowledge construction process, which is positioned within the social nexus of the farming communities. Thus, farmers' knowledge includes both experiential and social dimension. Blackstock et al., (2007) claimed that applying scientific knowledge that has been shaped to create sustainable paths of development involves adjustments in line with the socio-environmental conditions in which it will be executed. Application and/or execution largely entails a philosophical change in the understanding and appreciating the practices utilized by the different actors.

Agricultural Practices and Productivity

Agricultural productivity development determines the intensification and rise in crop yields against a given number of inputs or the decrease in contributions and inputs per a given level of productions. Specifically, it determines and evaluates the efficiency with which the farm inputs used to produce the crops realised by the farmer (Mechri et al.,2017). Irrigated farming productivity, profitability and efficiency are at the core of numerous debates, policies and measures regarding the agricultural sector particularly the smallholder farmers. Notably, the focus placed by the Sustainable Development Goals on agricultural productivity and profitability highlights several reasons for which prudent water resources use in irrigated faming targeted to increase water use efficiency is necessary. Information on crop productivity is related to numerous indications of the Sustainable Development Goals, particularly quantity of crop production, average income of smallholder food producers, as well as share of agricultural area under fruitful and justifiable agriculture.

The African Union has formulated "Agenda 2063" as a strategic structure for the socioeconomic revolution of the continent over the imminent half a century. It reinforces on, and pursues to hasten the implementation of previous and prevailing continental ideas for growth and sustainable development. Several countries have introduced strategies that will support to improve agricultural productivity, exclusively in emerging nations where agriculture is the main economic driving force and the productivity gap among the primary sector and other industries and services is the extensive (Lagakos et al.,2014). Improving crop productivity is vital because of its effective contribution to poverty drop through vibrant food security and higher household revenue.

The essential factor of agriculture, particularly, crop productivity in the economic and social agenda of emergent countries was strengthened by the Malabo Declaration, which has put crop productivity development at the hub of Africa's objective of achieving agriculture-led evolution and satisfying its aims of food and nutrition security (De Pinto, and Ulimwengu 2017). The Declaration emphasised the need to end hunger in the African continent by 2025, even though it was tall order, by at least doubling crop productivity

Basic Concepts and Explanations

But a question should be asked; "How can agricultural productivity be explained?" Many books, research articles and documents have defined 'productivity" as a share of a dimensions measure of output to a dimension measure of input used (Kathuria et al., 2011; Syverson 2011). At its most basic level, productivity commonly determines the amount produced by a defined group that are provided with some resources and inputs at a specified time. More often productivity can be determined for a single entity, for instance crop yield at some geographical area. The determinant commonly reflects the decisive purpose for the analysis. If for instance, the aim is to make a comparison of crop yield between farm irrigated plots, then actions to measure crop yields at micro-based are, therefore, required. However, if the objective is to assess national irrigated farming policy, then macro-measures are vital. Whereas the desired purpose may vary, the dimension issues linked to deriving the different pointers are necessarily the same (Kamara et al., 2019). While the data requirements may vary based on the type of need: farmer-plot-level productivity amount for a crop and input, for instance, farmer labour productivity of maize at plot level, may essentially require rudimentary information on output quantities and input use, although producing aggregated measures largely requires valuing outputs and inputs.

Productivity measurement originated from the micro-economics "theory of the firm" in which, inputs, the scarce resources, when mixed optimally and allocated can allow businesses to capitalise on profits subject to a cost constraint or to abate costs subject to production limitation (O. Hart, 2011; Williamson, 2002). Both scenarios may result with input apportionment that is efficient or best. Productivity is considered in this study because, through increased crop yields, smallholder farmers can better allot the scarce resources to other pursuits that are more profitable. In this way, productivity can lead to higher national revenue by virtue of input reallocation that are used proficiently and transferring the unused inputs or surplus to other equally productive endeavours (Foster et al., 2008). Both of these results stem directly from productivity analysis. In its modest procedure, productivity determination expounds the connection between the production of a product such as good or service against the inputs used to produce that commodity.

Methods and Issues Review of Productivity Assessment

It is well known that economic development relies both upon the usage of factors of production like capital, labour, innovation progress and. efficiency in resource use. This efficiency in resource utilisation is more often considered as productivity. Some experts have recognised that growth and development in productivity is the only credible conduit to intensify and enhance the standard of living and is therefore one of the factors that measure people's welfare (Olabi and Abdelkareem 2022; Velenturf and P. Purnell 2021; Vinelli and E. Weller 2021). The importance of economic evolution is less meaningful if it has not influence output growth and hence the living standards of poor people. This productivity development can be influenced by numerous factors that include investment in human capital through learning and training, infrastructure, research and development disregarding vigorous business environment.

Productivity assessment methods characteristically comprise pursuing the output produced relative to the resources used and strategies that include time-based measures for example the number of hours worked), output-based measures such as the number of maize bags produced, which may be referred to as key performance indicators. However, there are some pertinent factors related to the accuracy and impartiality of these appraisals, comprising likely bias, lack of context basis and problems in measuring complicated work tasks. In this respect, in irrigated farming, productivity is naturally measured by computing crop water productivity in terms of the ratio of crop productivity as an output per unit of irrigation water applied as an input. This computation, fundamentally, indicates how much crop is harvested per a cubic meter of water applied. This is the easiest way to evaluate efficiency in irrigated agriculture.

Profitability in Smallholder Irrigation Systems

Smallholder farmers' engagement in smallholder irrigation facilities is significant for boosting crop productivity, ensuring food security, profitability and encouraging sustainable rural development globally (Kapari et al. 2023). In the global south, where smallholder agriculture is predominant, water resources are commonly scarce, such that implementing and operating small-scale irrigated farming systems is particularly decisive. By revolutionalising sustainable farming within smallholder irrigation systems, smallholder farmers around the world generally and Malawi particularly can be instrumental in reducing poverty and improving food security through conservation of natural resources thereby encouraging long-term agricultural sustainability.

Profitability in smallholder irrigation systems can be described as the ability of a smallholder farmer engaged in an irrigation system to generate sufficient revenue from crops produced to cover all related expenses that may include the primary investment in irrigation infrastructure, operation costs, labour, and other farm inputs (Bjornlund et al., 2017). The most import factor is to have a positive net profit. Thus, the farmer makes more money from the crops grown than they are paying to produce them. The prevailing conventional perception is that farmer participation in learning how to minimise water application and market-oriented production have potential to encourage and increase agricultural productivity which leads to higher profitability, food insecurity and poverty reductions (Akpan & Zikos, 2023; Mdoda & Obi, 2019). Nevertheless, in the midst of numerous farming challenges, misuse and too much water application have performed miserably to be transformative for farmer households in irrigated farming facilities. As a result, socio-economic welfare has been declining in recent years.

Nevertheless. profitability can be challenging in smallholder irrigation facilities due to such factors as expensive startup investment costs, small plot sizes, restricted access to markets, and more expressively poor water resources management practices. However, the latter can be meaningfully enhanced with suitable crop varieties, resourceful irrigation technologies, strong and lively farmer learning (Ringler et al., 2020). Besides, vigorous institutional support that inculcate for increased crop yields and market access can eventually lead to better farmers' livelihoods (Kingiri, 2021). It should be mentioned that cautious attention of local circumstances and limitations are crucial for irrigated farming sustainable achievement.

Adoption of Technology and Its Influence on Household Welfare in Africa

Water resources use in irrigated farming is one of the most poorly managed resources, particularly in smallholder irrigation facilities in the developing world (Giordano et al.,2019; Mupaso et al., 2023). Approaches of distributing water are very sensitive to issues like availability and accessibility, informational and environmental problems, institutional and political settings, as well as the presence of externalities, that encourage it necessary to design water distribution mechanisms accordingly. A consequent to the dilemma that farmers are currently meeting due to CC is to adopt a technology that may improve the situation.

Technology adoption can be explained as a process through which people, entities as well as organisations accept, integrate, and use newly introduced technologies. As a concept, it may sound simple however acceptance and adoption of a new technology in farming systems or at an organisation level can be challenging (El Bilali et al., 2021).Technology adoption and its subsequent use have profound impacts on culture, economy, and. Society values. The technology itself can increase efficiency, generate new business prospects, and eventually improve quality life of targeted groups (Alhadeff-Jones, 2013). Effective planning, organisation and management of technology adoption process is vital for taking advantage of technological innovations benefits. There are five phases of technology adoption and viz: innovators, early adopters, early majority, late majority, and laggards. These phases define how people accept, adopt and use new technologies over time and it popularly known as the "Technology Adoption Curve" (Hoang, 2024). It is, however, extensively recognised that farmers are informed about the existence of effective and efficient of innovative agricultural technology through interfacing with other farmers and extension workers either within the same locality or field visits (Genius et al., 2014b). Technology adoption in irrigated farming is therefore crucial as it significantly increases water use efficiency, crop productivity, household profitability, and contributes to sustainable agriculture by optimising water usage and reducing environmental degradation particularly in areas with limited water resources by permitting smallholder farmers to produce more food with less water.

According to literature, some of the key factors persuading technology adoption include: apparent utility, compatibility, relative advantage, difficulty, societal influence, cost, training availability and user innovativeness just to mention but a few. It is familiar that for a technology to be accepted and adopted in the future will profoundly be influenced by the developing societal needs and expectations particularly in this time and age. The integration of technologies such as soil water and nutrient devices into daily lives of farmers in smallholder irrigation facilities will present new challenges and opportunities for adoption (Wakweya, 2023). Institutions and organisations that remain proactive and adaptable in responding to CC trends will be well equipped to efficaciously mix and apply available new technologies. More importantly, technology is considered to describe the physical water distribution infrastructure, a component of the irrigation facility infrastructure and the in-field equipment, its design, construction, operation and maintenance.

Smallholder Farmers in the Global South

The rural residents in Africa particularly Sub-Saharan Africa (SSA) comprise very poor smallholder farmers and earn their incomes generally from rain-fed agriculture which is climate-sensitive. Considering that the African population will double by 2050 to above 2.0 billion persons, several governments are challenged by the criterion to balance between increasing and diversifying food supplies and sustaining easily available natural resources on which humanity essentials are based (Gerland et al., 2017; UN, 2015). Food insecurity and poverty levels are among the key tasks to achieve Sustainable Development Goals target 2.1 in Sub-Saharan Africa (Juju et al., 2020). To realize this goal, countries must focus on efficient use of freshwater to meet irrigation and consumption needs.

As is the case with emerging nations globally, agriculture is recognised as the key issue of the national economic development equation, even though its productivity has been slowly improving since the 1990s, however, it is now just above demographic growth (Peterson, 2017). Currently, agricultural production, particularly in the Sahel and the SAR, has been associated with low productivity compared to other emerging areas (Bucci, 2015; Moyo, 2016). Nearly 25 percent of individuals above the age of 15 years were hungry for a whole day due to a lack of financial or other resources for food (Roser and Ritchie, 2019).

In the Sudano-Sahelian Region, irrigation is alleged as contributing to high-value production where 58 percent of the value of agricultural output has been registered. Even so, there remains huge areas of untapped potential (van Der Wijngaart et al., 2019). Similarly, in the SAR, there are areas where river basins have significant undeveloped irrigation. Reports indicate that only about 6 percent of land in Africa is irrigated against the proportion to cultivated land compared to 14 percent for Latin America and 37 percent for Asia (You et al., 2011). In Malawi for example, the potential for irrigation remains, mostly, untapped. From an assessed potential of 407,862 hectares, nearly 104,634 hectares have been developed representing 25 percent of the possible area (DoI, 2016).

The limited land area under irrigation contributes to low agricultural production and productivity that leads to food shortages during periods of droughts, excessive dry spells, erratic rainfall patterns, and sometimes floods whose frequency has been increasing because of climate variability influences (Magombo and Kosamu, 2016; Savo et al., 2016; Saruchera, 2019). Climate variability and change in Malawi are significantly posing a threat to economic growth, long-term fisheries success, as well as the welfare of the majority of the rural population (Limuwa et al., 2018). Besides, evidence indicates that population growth has exacerbated the situation and the population growth is projected to reach close to 19.1 million by 2020 (Kandoole et al., 2019; Mussa and Masanjala, 2015).

This literature review draws on secondary data sources concerning academic literature, available databases, and government policy reports. The key purpose of this literature review is to present a synopsis of current literature (2015 onwards) on the assessment of potential utilisation of new technologies and sustainable irrigation development internationally and in the African Continent particularly. The main issues include food security and poverty, the influence of water use efficiency and productivity, linkages between irrigation potential and water resources management, and lessons and approaches to assess the potential of sustainable irrigation development among others. Accordingly, books, scholarly publications, consultancy reports, government policies, international organisations (International Fund for Agricultural Development (IFAD), Food and Agriculture Organization (FAO), International Water Management Institute (IWMI), bank reports (World Bank, African Development Bank Group (AfDB)) as well as Internet sources were used. For academic literature, search engines like Google Scholar, ProQuest, and Scopus were used.

The main terms for specific searches included “SSA and Sahel” “agriculture”, “barriers”, “ behaviours”, “climate change”, “climate resilience”, “climate variability”, “experiential learning”, “farmer behaviour”, “integrate water management”, “integrated watershed management”, “irrigation”, “irrigation investment”, “irrigation potential”, “food security”, "land-use change", "nutrient management", “productivity”, “profitability”, “social learning”, “theory of reasoned action”, “theory of planned behaviour”, “water use efficiency”.

Many investigations concerning irrigated farming globally, regionally as well as locally have looked at the potential development of irrigation. The parameters considered the characteristics of agricultural practices, land tenure, water resources availability and quality, irrigation innovation, prevailing infrastructure, and socioeconomic characteristics. The latter essentially looked at demography, investment requirements, policies, and market facilities. From a global perspective, intricate irrigation systems are, particularly, linked to larger social, economic, cultural and political issues in a given setting (Jarzebski et al., 2020; Sani, 2017).

Due to a scarcity of literature on technology to increase water use efficiency in Malawi, the literature review presented concentrates on studies from the African Continent and SAR when assessing productivity and profitability regarding social and experiential learning in SIS in Africa and Malawi from 2015 to present, was queried from the ProQuest, 489 articles were identified. Whatever the scale of the study may be, literature searches intend to acquire knowledge that is already prevailing and support decisions that the researcher can make. The search engines used allowed for targeting unambiguous information and access to relevant scholarly databases, journal articles, citations, and educational resources. They are expedient to use and save time that would otherwise be spent looking for relevant information from library shelf-to-shelf. But querying "evidence of smallholder farmers learning and acceptance of nutrients and water-saving monitoring tools in irrigated agriculture from 2015 Africa, SAR and Malawi."

To sustain the performance of SIS, it is imperative to involve all stakeholders including farmers themselves to enhance their management capacity. Levidow et al. (2014) acknowledges that learning can enhance water-efficient irrigation as well as recognizing the prospects, challenges and difficulties of innovative practice. Based on the foregone, Table 2.1 shows the results of literature review that the researcher conducted which comprised of Doctor of Philosophy (PhD) and Master of Science theses, journals, reports, books etc related to learning by farmers.

Table 2.2

Literature Search

Source Type	Africa	SAR	Malawi
PhD and MSc Dissertations Theses	1062	313	202
Scholarly Journals	1306	1299	575
Reports	1213	1142	586
Seminal Literature	494	478	276
Books	1209	1192	585
Total	4790	3946	1948

The study expects to understand how soil water and nutrient-saving technologies could be used to improve the smallholder irrigated farming sub-sector of Malawi. Having presented the literature review, it is important to direct how the information to be gathered will be used to determine the salient issues being investigated. In any research, the relevance of creating theoretical and conceptual frameworks to guide how it can be conducted cannot be overemphasised.

Technology Use Impact on Household Food Security and Poverty

Water scarcity for farming and productive agricultural use remains a daunting task and challenge for the majority of poor smallholder farmers, who are the majority of producers in sub-Saharan Africa (Agyenim-Boateng et al., 2015; Goedde et al., 2019; Li, 2020). Reports indicated that in 2006, nearly 225 million hectares of land were farmed in sub-Saharan Africa. However, the total area prepared for irrigation was 7.2 million hectares. This is just 3.2 percent of the total farmed area devoted to irrigation. Irrigation is nonetheless a key contributor to agricultural intensification. One of the vital measures that are of particular importance has been noted by many to be appropriate and simple technologies to augment water supply and use, which illiterate smallholder farmers can be able to understand and use. Thus, technology introduction in irrigated farming can improve crop yields and quality, reduce water wastage, increase food security and profitability.

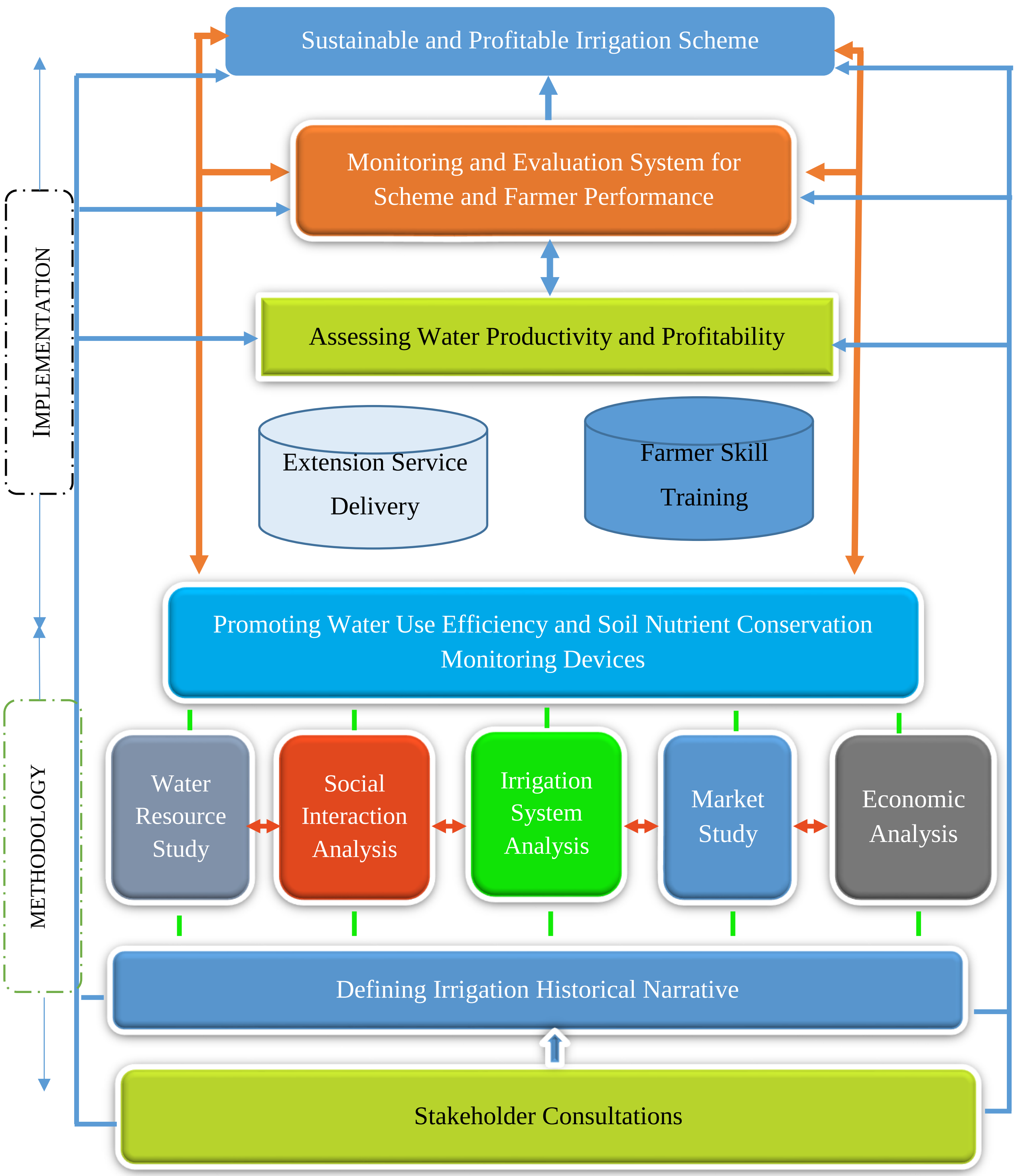
The introduced technology can provide smallholder farmers with methods and approaches that can precisely control the timing and amount of water to be applied and thereby easily meet the crop water requirements (Mloza-Banda, 2006). Farmer participation in water distribution governance contributes to better decision-making regarding the irrigated farming business. Participation in irrigated farming can be describes as a process by which all stakeholders affect and have control over the activities of the development initiatives through making decisions, and availing the resources that affect them (Kandil, 2023). Besides, participative governance would allow joint decision-making by the stakeholders in the effective utilisation of natural resources and reserved for sustainable irrigation.

Smallholder irrigation on the African Continent has been encouraged since the early 1900s as one way of making sure that food security is attained as well as improving livelihoods of rural people (Shah et al., 2020). Many smallholder irrigation schemes are currently being revitalised globally, a process which intends to restore and improve the usefulness and productivity of irrigation facilities. It is a schedule whose aims are to improve farm productivity, improve rural communities' flexibility to food uncertainty due to the adverse influence of climate change and weather variability (Wakweya, 2023). Besides, it frequently includes refurbishing damaged infrastructure, upgrading and introducing modern technologies, enhancing water resources management practices, and empowering smallholder farmers to better use the systems appropriately (Fanadzo & Ncube, 2018).

The main aim is to intensify crop productivity by maximising and increasing water use efficiency. This revitalisation also includes the modernisation of irrigation schemes in terms of technical and managerial advancement as against mere rehabilitation combined with institutional reforms, intending to improve resource deployment and water delivery services to farmers' plots. Currently, one of the key challenges is to achieve food security with its consequent intensification of global food production. In the year 2015, national leaders from 193 countries accepted sustainable development goals to terminate poverty, protect the environment and promise wealth for all with sustainability (UNGA, 2015; Lee et al., 2016). Figure 2.4 is a conceptual framework that was used by Mwendera and Chilonda (2013) studying the revitalisation of small-scale irrigation schemes in Southern Africa emphasising on water utilisation. The revitalisation agenda is generally based on the consideration that smallholder irrigation schemes comprise four equally connected systems: the physical system, the cropping system, the economic system and the social-organisational system.

Figure 2.4

A conceptual framework for assessing water productivity and profitability in irrigation scheme



Adapted from Mwendera and Chilonda (2013)

The leaders, particularly, identified Goal 2: "End hunger, achieve food security and improve nutrition and promote sustainable agriculture" as well as "Goal 6: "Ensure availability and sustainable management of water and sanitation for all." Out of the 17 sustainable development goals these two goals are to be on the top of development agenda items on their national development priorities (Morton et al., 2017). The revitalisation goal is to support farmers increase household profitability and easily access markets so that they can sustain their families. To improve agricultural productivity in smallholder irrigation systems, farmer learning has been noted to be one of the missing linkages in smallholder irrigation development and numerous failures have been ascribed to a lack of adequately skilled farmers and extension staff, particularly in water resources utilisation (Fróna et al., 2019; Mehrabi et al., 2018; Ranganathan et al., 2018; Béné et al., 2015). Hence, the smallholder irrigation revitalisation programme (SIRP) in Malawi aims to support farmers improve their access to water, markets and farm inputs and adopt climate-smart farming practices.

Reports indicate that the population of the world is increasing by 83 million people annually and is likely to reach 9 billion people by 2050 (Radavoi, 2017). Thereby, competing demands will escalate the risk of localised conflicts due to water shortage (Fröhlich, 2012; Pereira, 2017; R. Smith, 2017). In this regard, two main research themes were considered to be operational viz: on-farm and scheme levels and these will be expanded. Firstly, the on-farm irrigation system theme is mandated to encourage farmers to view irrigation as a component of integrated water resources management. More importantly, is the connection between on-farm irrigation systems and irrigation scheduling approaches, i.e. irrigation performance, profitability and environmental concerns.

Management at a smallholder irrigation facility characteristically includes a farmer-centric strategy where local water users' associations (WUAs) play a significant role in delivering water fairly, resolving conflicts, monitoring water usage, and executing sustainable practices, frequently with help and support from extension delivery service staff and government agencies (de Silva et al., 2019; Fröhlich, 2012; Ogilvie et al., 2019). All these efforts focus on efficient and judicious water use. Moreover, crop diversification is important emphasised as well as capacity building among smallholder farmers to maximise crop productivity from the limited water available. Thus, Theme Two looks at the social, cultural, institutional and policy constraints operational at the scheme level.

The basic idea is to promote effective and efficient sustainable methods for water application on farmers' plots and generally at the scheme level to improve crop productivity and profitability. Numerous systems and devices have previously been developed to determine when crops need water and how much water must be applied. These consist of different soil nutrient and crop monitoring methods, the more common soil water balance, and scheduling simulations. The use of these different scheduling devices depends on the input needs linking to types of data, for instance, weather, soil and crop, as well as the frequency of data collection. Crop water requirement assessments play crucial roles in several models and many water stress conditions. The detection of constraints and needs for farmers and managers is vital in the choice of suitable water scheduling approaches.

Seeing that disappointing results have been noted, the new direction to enhance productivity and increase farmers' profitability includes proper design installation and maintenance of irrigation structures and water distribution system networks as the second theme. Soil moisture monitoring, technical and management measures to improve water infiltration and retention capacities of soil nutrients should be encouraged (Cole et al., 2017; Karlen et al., 2017).

The demand pressed on water resources highlights the environmental, hydrological, social, and economic inter-dependencies in river, lake and aquifer systems. These interdependencies necessitate more integrated approaches to utilising and managing water and land resources. Based on the judicious use of water resources on a watershed vis-à-vis catchment basis, the International Conference on Water and the Environment held in Dublin in 1992, formulated four guiding values associated with water use. These values are briefly discussed below.

Value No. 1: Freshwater is a limited and susceptible resource. Effective water resources management essentially connects land and users across the catchment area. Vannevel and Goethals (2020) argued that there is an increasing agreement that sustainable development needs behavioural change underpinned by a strong decision-making process. Globally, agriculture accounts for roughly 70 percent of freshwater withdrawals, followed by industry which is 18 percent and domestic uses 12 percent.

Value No. 2: Water resources management and development should follow a collective action approach that includes users, planners, policymakers and other stakeholders at all levels (Wehn et al., 2018; Tengberg and Valencia, 2017). This Value No. 2 aims to promote community awareness and support data collection to lessen water pollution and advocate for improved local water conservation practices. Importantly, it encourages a synchronised development and management of water use, land, and allied resources

Value No. 3: Women play a key role in the delivery, management and protection of water. This is a vital role for women as providers and users of water and guardians of the active environment have hardly been considered in institutional programme items for water resources development and management. Acceptance and implementation of this value, therefore, need constructive policies to address the specific needs of women. This value is sensitively essential for the evolving world where millions of women lack access to water for basic essentials.

Value No 4: Water is an economic resource in all its contending uses and must be known as an economic good. Based on this principle, it is important to acknowledge first the fundamental right of all people to have access to clean and quality water at a reasonable cost. Notably this value, has noted several countries considering integrated approach to water resources management (Mehta et al., 2016; Van Koppen et al., 2017).

Behavioural Change Models

The value of farmer participation in irrigation system design and management of water resources has been emphasised in previous studies. In a time of increasing pressure on water resources, it is not surprising that farmers' behaviour is being considered to play a significant role in increasing water use efficiency and also providing environmental stewardship. However, the growing challenges and problems to ensure that water supply demands are successfully met require effective management (Zhang and Vesselinov, 2017; Zhang et al., 2020). Because of ongoing industrialisation and urbanisation developments, production and service sectors are increasingly extracting limited water resources, while unintentional and unnecessary water consumption is leading to the depletion of surface and groundwater resources, with substantial negative costs for natural ecosystems.

Water application on smallholder irrigation schemes has been reported to consume nearly 90 percent of a nation's water resources as argued by Mhembwe et al. (2019). As a consequence, smallholder farmers represent an important target that can encourage water-saving and water-efficiency improvement policies. So, for water resources to be successfully utilised and managed, there is a need for good governance, which is all about policy alternatives: how the administration makes the best use of the powers accorded and the resources entrusted to it by the users who also manage their relationships with enterprises and other stakeholders. Because of climate change and variability, there is a growing technological transformation that attempts to solve the lavish use of water resources and leaches out nutrients from crop root zones. Some leading scientists seek to influence the evolution of technological applications to the advantage of crop productivity (Jiao et al., 2016; Zwane, 2019). With the innovative and dynamic progress of technologies in the agricultural sector, how fast smallholder farmers accept these technologies depends on several factors such as availability of technology, relevance, farmers' needs, security etc. Literature addressing the farmers' acceptance and adoption of new irrigation technologies in the 21st century is available (Frisvold and Bai, 2016; Osewe et al., 2020; Salazar and Rand, 2016; Wheeler et al., 2017). However, a pertinent question that is in most instances asked is: "How is farmers' sensitiveness increased in water-saving and how are they encouraged to adopt water-saving measures?" Thus, discovering factors that most likely inspire smallholder farmers' adoption intentions could permit policy decision-makers to focus on them.

Determining farmers' intentions to adopt the new technologies that could improve water use efficiency is challenging, but using the Theory of Planned Behaviour, a recognised framework in psychological works, can be used to assess the determinants of smallholder farmers' behavioural intentions by considering their innovativeness, envisioned as their propensity to accept and/or adopt new technologies and their water footprint (WF) in irrigated farming. A WF is defined as the volume of freshwater smallholder farmers apply on their field plots for crop production processes. According to Hoekstra et al. (2012) WF indicator assesses virtual water use and water quality linked to goods and services consumed over a period. Situation water availability analysis emphasises the need to reduce WF production and increase water resources supply for sustainable irrigated farming development in arid regions. While water shortage is a concern associated with available freshwater resources relative to the its use, a WF measures quantity of water used to produce a product.

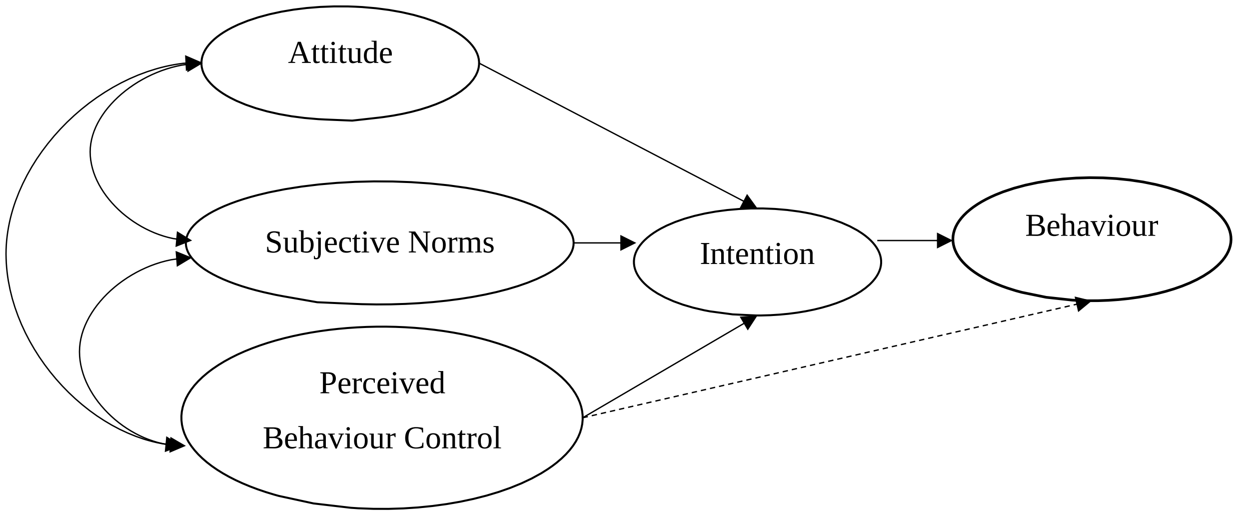
Theory of Planned Behaviour and Water Use Efficiency

The Theory of Planned Behaviour (TPB) is a socio-psychological concept that assumes that an individual's intention to perform a certain behaviour is the powerful judge of that behaviour. Otherwise, an intention is a function of three primary aspects. First is an attitude toward a certain behaviour meaning the level of a person's constructive or unconstructive propensity towards an explicit behaviour; second is a subjective norm as the degree of social burden that persuades others to exert on individuals that may prompt them to either adopt or not adopt a certain behaviour; and lastly, perceived behavioural control, which is an individual's awareness level of how easy or difficult to attain a specific behaviour. Each of these constructs can be derived from a set of views and opinions that correspondingly concern: the benefits vs. drawbacks related to the considered behaviour (behavioural beliefs); an individual or institution that may back it or not (normative beliefs); and the perceived comfort vs. struggle of carrying out it (control beliefs).

This theory has been used to evaluate cognitive factors that determine people's water-saving and reduction behaviour and, rarely, to assess farmers' water-saving intentions (Gilbert et al., 2020; Pino et al., 2017). Irrigated farming, as the highest user of freshwater resources, by increasing water use efficiency may significantly influence developing and instituting better water-saving strategies. In this respect, the Theory of Planned Behaviour Hs been extensively used to explain individual behaviour changes in times of environmental threats (Pino et al., 2017). The TPB can be applied to appreciate, recognise and predict water use efficiency in irrigated farming facilities through examining and analysing how a farmer's attitude towards water resources conservation, perceived social norms, and perceived behavioural control influence intentions to use water more efficiently, eventually leading to genuine water-saving behaviours. Figure 2.5 provides the linkages important to behaviour transformation

Figure 2.5

The Theory of Planned Behaviour



Source: Ajzen, 1991

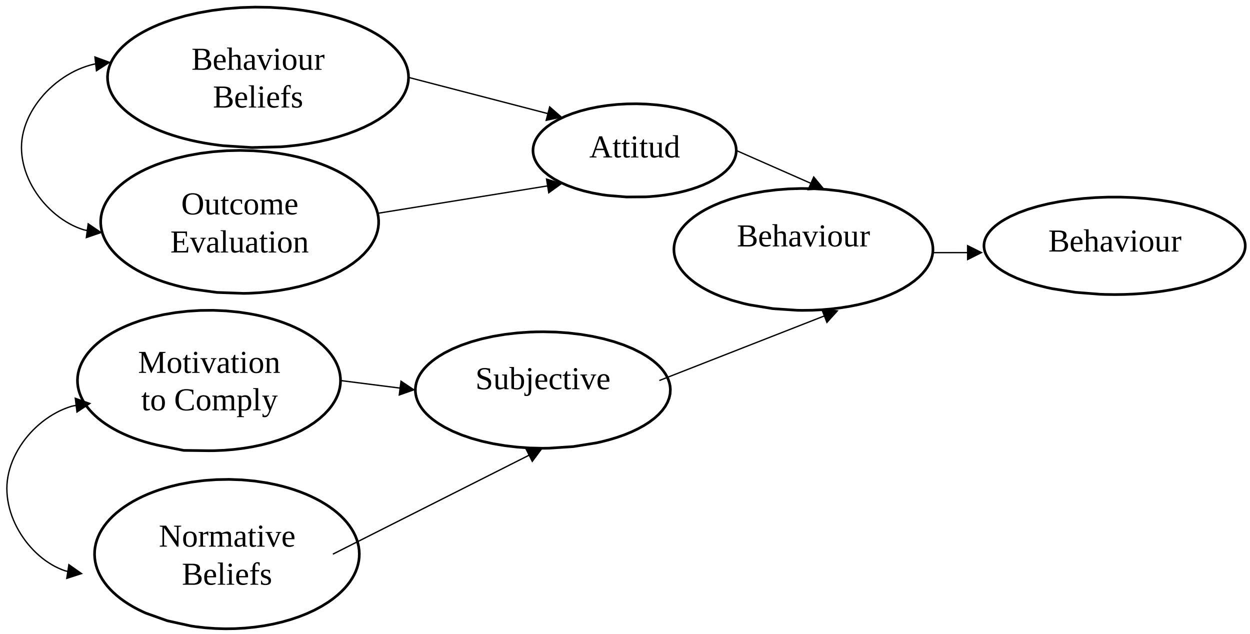
The Theory of Planned Behavior (TPB) suggests that a personal's learning, acceptance and adoption of a novel behaviour is mostly driven by intention to perform that accepted behaviour. The personal behaviour in most situations is motivated by own attitude towards the behaviour acknowledged to be a subjective norm (Sia and Jose 2019). A subjective norm is an individual's acuity of how peers expect them to behave. It is one of factors in TPB, which envisages how likely someone is expected to perform in a certain way. Another component in TPB is perceived behavioural control which explains how easy a person believes s/he can perform the behavior); fundamentally, the more positive the attitude one has, the stronger the social support, and the higher the perceived control such that it may be more likely that someone is able to engage in a new learning activity (Hagger et al. 2022).

The Theory of Reasonable Action developed by Fishbein and Ajzen in 1975 is considered as one of the most popular theories used and is about one factor that determines the behavioural intention of the person's attitudes toward a certain behaviour, sequentially, it is a function of their attitude towards the behaviour and subjective norms. A person's choice to participate in a specific activity that may influence his/her behaviour can be grounded in the effects he/she believes will come from because of the result of performing that behaviour. Consequently, to perfect the determination of a person's intention towards a behaviour, Ajzen developed the

Theory of Planned Behaviour (Figure 2.5). This theory has been applied in several research studies n irrigated farming to assess the cognitive factors impelling water conservation behaviour and to review behavioural patterns in irrigated farming (Chaudhary et al. 2017; Chaudhary et al., 2018; Gibson et al. 2023). It is about one factor that regulates the behavioural intention of the person's attitudes toward a certain behaviour as shown in Figure 2.5. The first two factors are the same as the Theory of Reasonable Action (TRA) in Figure 2.6 below. The third aspect that is known as the perceived control behaviour is the control that users, in this study, are smallholder farmers, observe that may constrain their behaviour and prompt them either to accept or reject what is being promoted. The TRA advocates that an individual’s behaviour is largely determined by their intention to achieve and perform the acquired behaviour, once the behaviour is well integrated is in turn influenced by the individual’s attitude towards the behavior and the subjective norms they perceive around them. Fundamentally, people are more likely to perform a behaviour if they have an optimistic attitude towards it and believe that it is important as others approve of it. What is relevant is that individuals consider the consequences of the behavior before that can change their behaviours.

Figure 2.6

The Theory of Reasonable Action



Source: Fishbein and Ajzen, 1975.

To perfect the determination of a person's intention towards a behaviour, Ajzen developed the Theory of Planned Behaviour. This theory has been applied in several research studies to assess the cognitive factors impelling water conservation behaviour and to review behavioural patterns in irrigated farming (Chaudhary et al., 2018). It is about one factor that regulates the behavioural intention of the person's attitudes toward a certain behaviour as shown in Figure 2.5. The first two factors are the same as the Theory of Reasonable Action in Figure 2.6. The third aspect that is known as the perceived control behaviour is the control that users, in this study, are smallholder farmers, observe that may constrain their behaviour and prompt them either to accept or reject what is being promoted. For instance, a farmer, on his/her own, can ask a question such as: "Can

I participate in farmer’s water use efficiency training and what are the requirements?" The impression that behavioural change is accomplished depends jointly on incentive (intention) and skill (behavioural control) is by no means new.

The response may indicate what the farmers' intention will be, that could be if I participate, I may learn how much water to apply and its frequency so that the problem of water scarcity can be surmounted. The answer is based on water shortage and conflicts which are considered a norm in smallholder irrigation schemes as some farmers like to breach the canals for water supply distribution (Manero, 2018). Understanding farmers’ behaviour, motivations, and perceptions towards crop productivity through increasing water use efficiency and reduction of nutrient leaching can influence how smallholder farmers translate water-saving into crop productivity and profitability.

Improving evaluations of drought risks for crop yields and household incomes through farmer learning in selected smallholder irrigation schemes requires a better understanding of the interaction between individual adaptation decisions and drought risk projections. Thus, farmer-based modelling has gradually been used to capture the interaction between individual decision-making and how the environment is to be cared for. Besides, changing smallholder farmers’ behaviours is a precarious challenge for extension front staff who persuade and encourage good irrigation practices and promote relevant technologies for water conservation. Reports indicate that various messages may be used to influence two predictors of behavioural commitment that are informed by the theory of planned behaviour, i.e. attitude and perceived behavioural control. This theory upholds three basic constituents, namely, attitude, subjective norms, and perceived behavioural control, together shape an individual's behavioural intentions.

Institutions and Organisations in Irrigation facilities

Institutions and organisations are very important crucial in irrigation facilities because they provide better management and the equitable distribution of water resources, safeguard appropriate maintenance of irrigation infrastructure and appurtenances, they simplify conflicts among farmers and provide resolution among water users through promotion of sustainable irrigated farming practices, finally capitalising on the efficiency and effectiveness of irrigation arrangements, particularly in areas with limited water resources availability in which impartial access is very necessary (Aarnoudse et al.,2018; Kibret et al., 2024; Nhundu et al., 2015).

Institutional and organisational characteristics are essential in studying farmer learning in SIS for a number of reasons. For example, the chances could be farmers may strengthen their farming business and gain easy access to production factors. However, farmers are also helpless by several factors such as the absence of rules to regulate water resources use besides local knowledge to support farming, and the average crop production that is still below the average output. Regarding institutional characteristics, policy and controlling contexts influence farmer decisions and participation in learning groups as well as affecting farmer incentives. Institutions shape farmers' social norms and uphold cultural values, inculcating farmer behaviours that influences farmer organisations (Wijana and Setiawina, 2021). While organisational attributes influence learning and decision-making by understanding resource allocation influencing farmer access to information, innovation and farmer networking and partnerships thereby enhancing farmer learning and collaboration.

Various reports indicate that smallholder farmers in many countries are facing problems of food insecurity due to climate change and variability that induce droughts and floods, besides improper effective use of water resources in their irrigation schemes. Rainfall distributions have become more erratic and unreliable. Experiencing such challenges, several smallholder farmers have tried to improve household food security and reduce poverty but have failed. While the country has relatively ample water resources and fertile land, irrigated farming has not developed to a level that can be described as significant (Kumwenda et al., 2015; Nhamo et al., 2016).

Regulations, Institutions and Institutional Transformation

Rules, institutions, and institutional transformation are themes of immense interest in modern economics, political economy, and political science. According to Chikozho and Nhemachena (2017), several Sub-Saharan countries have begun appreciating notable development trends by adopting macroeconomic policies and institutions suitable to their circumstances, in so doing demonstrating that the economic renaissance in this part of Africa has great potential. The advent of political change and democratic dispensation have accepted and tolerated the determination of a fitting blend of policies and institutions that would allow achieving speedy socio-economic growth in most Sub-Saharan countries. This has been premised on the underachievement of socio-economic development. Some African countries have been constantly looking for ways to change their nation's economic landscape since attaining political independence in the 1960s but have failed.

But the question: "What are institutions?" Institutions are the people's formulated restrictions that make up political, economic, legal and social collaboration. They comprise both informal limitations such as agreements, prohibitions, customs, behaviours and codes of conduct and also formal tenets regarding constitutions, economic growth, laws as well as property rights (Acemoğlu and Robinson, 2016; Freire-Gibb and Tapia-Carrillo, 2019; Jakšić and Jakšić, 2018). Institutions have intentionally been shaped by societies to establish order and minimise insecurity in exchange. Together with the value limitations of economics, they outline the selection set controlling the operation and production costs and, therefore, the viability and profitability of engagement in lucrative business activity.

However, in irrigated farming, a pertinent question to be asked is: “What makes it vital to limit human engagement with institutions?” The matter can be briefly explained by using a game theoretic situation. For instance, profit maximisation may usually make it useful for people vis-à-vis smallholder farmers to liaise with other players in the agricultural sector when the issue being encouraged and played is repeated. Issues of fertilisers, pesticides and other agricultural chemicals' presence are lacking information availability becomes a critical issue. Once they possess thorough information about the other player's past performance, and when there are small numbers of players, they may tend to try it, however, the game being played or tied may be turned upside down (Mäntymäkiet al., 2020). It can be argued that people’s cooperation, in most cases is challenging to maintain when the issue is not repeated or otherwise there is an endgame, meaning when information on the other players is absent or missing, and when there are increased numbers of players.

Two main themes were considered: on-farm and scheme. However, these will be expanded. The on-farm theme is mandated to encourage farmers to view irrigation as a component of integrated water resources management. The basic idea is to promote effective and efficient sustainable methods for water application in schemes to improve crop production and productivity. Seeing that disappointing results have been noted, the new direction to enhance productivity and increase farmers’ profitability includes proper designing, installation and maintenance of irrigation structures and water distribution system networks. Soil moisture monitoring, technical and management measures to improve water infiltration and retention capacities of soil nutrients should be encouraged (Cole et al., 2017; Karlen et al., 2017). However, the on-farm conditions for different irrigation schemes may vary in terms of numerous factors like weather, location and geological considerations as well as available water resources quantities.

It may be noted that the function and role of the government in water resources use and development may be different for each irrigation scheme in the country. Regarding how water use may be effectively used, its organisation is tentatively at two different levels: firstly, there is an exclusive organisation that has full responsibility and authority at a local level and secondly, various stakeholders allocate water management based on several reasons in water development and its utilisation.

To improve water resources use and irrigation efficiency, all scheme organisations and entities must thoroughly liaise together. In this respect, the active participation of various organisations and farmers is advisable so that crop productivity is improved and farmers get the worth of their inputs (Kirui and von Braun, 2018; Pék et al., 2019). Actions under the scheme theme point at farmer techniques and devices. Orderly practices and knowledge are needed to enhance the efficiency, productivity and sustainability of irrigation and drainage systems. Thus, some factors may not be part of this but are only such techniques as water-measuring methods and devices. The Government of Malawi has expressed decisive views regarding smallholder irrigation using user-friendly tools for increasing agricultural productivity. This was based on the preliminary results from the irrigation schemes using such tools (ASARECA, 2019).

Relevance of Institutions and Organisations

The absence of usefulness of the national system of agricultural institutions concerning the support rendered to smallholder irrigated farming is one of the major issues in Sub-Saharan Africa generally and Malawi particularly. There is apparent proof that key agricultural institutions concerning research, extension, credit and marketing are not operating as an integrated system in several countries in the region (Nwafor & Nwafor, 2020). It has been claimed that these institutions have not operated with a common vision or purpose to help smallholder farmers with irrigation schemes. It is also observed that public servants generally and their professions particularly, are unaffected by how smallholder farmers observe and assess their performance. This gloomy state of affairs is aggravated by the top-down philosophy, direct and consequent view of technical and institutional procedures that hinder smallholder farmers' participation in decision-making that concerns them (Eidt et al., 2020; Poole 2017).

Various reports indicate that smallholder farmers in many countries are facing problems of food insecurity due to climate change and variability that induce droughts and floods, besides improper effective use of water resources in their irrigation schemes. Rainfall distributions have become more erratic and unreliable regarding traditional farming seasons. Experiencing such challenges, several smallholder farmers have tried to improve household food security and reduce poverty but have failed. Malawi’s annual mean rainfall varies between 725 and 2500 mm and the long-term yearly average oscillates around 1140 mm. While the country has relatively abundant water resources and fertile arable land, irrigated farming has not developed to a level that can be described as significant (Kumwenda et al., 2015; Nhamo et al., 2016).

Reports provide that smallholder irrigation schemes misuse water resources as farmers think that water is a freely and naturally given commodity (Ireri, 2017; Pandey et al., 2020; World Bank Group, 2016). Concerning global freshwater management, irrigated farming bears special consideration, responsibility, and accountability, as water use accounts for more than 70 percent of all volumetric freshwater use globally. Thus, this status describes the reasons why the International Commission on Irrigation and Drainage’s Vision 2030 promises to recognise technical, practical, and institutional approaches to enhance water resources management, resolve likely inconsistencies between several aims pursued, explain stalemates, document and encourage trade-offs and sustainable solutions (Makin, 2020).

It has been observed over the years the interest in sensible selection analysis of institutions. From a horde of evidence illustrating the importance of a society's institutions in assessing its economic conclusions, substantial incentives have been received (Makin, 2020). Econometric investigations have determined correlations between institutional measures like the security of property rights, rule of law, trust, economic and political consequences with levels of production, saving, and fraud. As nearly 60 percent of the area in the Southern Africa Region is semi-arid or arid and undergoes periodic droughts complicated by the shortage and inappropriate water resources management on smallholder irrigation schemes, water user associations have proven to play a momentous role (Nhundu et al. 2015). Thus, water shortage poses challenges for agricultural resolves and presents undesirable moments on welfare, more explicitly in rural areas. It is in these parts that many are involved in agricultural farming for their livelihoods. This has contributed to a productivity decline. Declining crop productivity among smallholder farmers in sub-Saharan Africa remains a key hindrance to the continent's economic growth as agricultural production is dominated by rainfed farming and irrigation systems are very limited (Mabhaudhi et al., 2018). As a result, irrigated farming is the best alternative to food security.

Farmers' Decision-Making Process

Farmer participation in irrigation activities is dependent on many factors as such a decision-making process based on household circumstances is vital. The complication of the decision-making process underlying irrigated farming is reflected in the literature on irrigation. Salazar and Rand (2016) claimed that monitoring for pre-conditions that affect irrigation choices undoubtedly enhances an appreciation and comprehension of smallholder farmers' adoption decisions to participate in irrigation. The argument could be that a lack of knowledge about simple soil water monitoring devices in irrigation schemes could be the main hindrance to improving small-scale farmer productivity and profitability (Levidow et al., 2014). Within this argument, two pertinent themes emerge. One concerns precise issues that influence decision making and the other concerns the type of farming system adopted and its effect on water resources management. Furrow irrigation systems are widespread in Malawi in which water is supplied to the entire field (Chirwa et al., 2008; Kumwenda et al., 2015)

During this time and age, several issues are being outlined according to the different types of irrigation technologies and the underlying crop selection process (Sánchez Toledano, 2017). Literature reveals that there are noticeable differences in the comparative importance of decision factors about irrigation selection. Some factors are not exclusively economic but have proven to be of greater consequences that unsurprisingly influence crop production. Water application, for instance, has been noted to influence crop production, however, reports also indicate that it is misused simply because many smallholder farmers regard it as a gift of nature (Osage et al., 2020).

For proper water utilisation in irrigation schemes, farmers should know when and how much water to apply. Simple soil water and nutrient monitoring tools have been introduced in some irrigation schemes as such there is a need for farmer learning to understand how they operate and gauge water infiltration. But what is learning? Learning pertains to a transformation in behaviour that is practical, bringing about change and involves the acquisition of knowledge, competence, and attitudes related to occupation mastery. Most trainers lean profoundly towards a cognitive stance of learning, which provides a visible behaviour change formed by events within the environment (Danish & Gresalfi, 2018). Most grown-up individuals, to participate in most learning activities are usually motivated by some immediate household challenges or tasks that demand some appropriate decisions requiring certain knowledge or skills. The adults who become learners themselves commonly plan their learning activities. In such activities, they seek help from friends, associates, equals, members of their family, as well as neighbours. Nonetheless, specialised help makes up a small proportion of the resources required. Groups can also be a relevant pathway of learning and have been observed to be very efficient, particularly if group members want similar knowledge or skills such that the knowledge and skill sought are available within the group. Thus, a group can offer constructive and expressive benefits regarding enthusiasm, motivation and a sense of achievement (Darling-Hammond et al., 2020).

It can be argued that an adult's efficiency in learning in groups is hardly as great as it would be if trainers use one-to-one contact, however. The most notable and effective way of adult learning is where interactions with the learner are planned and organised based on a one-to-one situation to allow very detailed, and personalised outcomes for the learner to be achieved. Nevertheless, a key issue of valuing drivers of behavioural change through decision-making is where there is a desire of farmers to increase their awareness of climate change so that they can achieve uptake of mitigation practices and strategies to reduce misuse of water application on their fields in irrigation schemes. As such creating awareness is important as it helps understand the environmental circumstances that may lead to making better decisions that are more fulfilling, and of a greater sense of purpose.

Smallholder farmers are faced with a multitude of decisions to be made due to their circumstances. For them to adopt agricultural technologies, for example, that improve crop production and productivity a thorough understanding of how they make their decisions is necessary (Meijer et al., 2015). The decision-making process usually starts with what farmers perceive and understand about soil moisture and nutrient content, how they manage water resources at the field plot level and what they are able and eager to risk if water application is varied even though informed that the performance is better. By understanding farmers' decision-making processes and how they learn about the social, economic and cultural factors that have a bearing on crop production decisions, particularly about the adoption of new methods and technologies, improvement in farmers' livelihoods can be guaranteed. This is, particularly, important since the majority of smallholder farmers manage risks daily to secure their livelihoods

(Meijer et al. 2015). By merging local knowledge with science, the value can be significant as farmers actually know their circumstances and challenges and thereby contribute importantly to their circumstances.

The way decisions are made to accept and adopt a technology that can improve farmers' household circumstances takes time for an individual to decide what to do (Liu et al., 2018; Mankad, 2016). Deciding how to adopt technology is a mental process that comprises knowledge, persuasion, decision, implementation and confirmation. This process is also affected by variables like personal and social characteristics and the perceived need for innovation. The diffusion of innovations theory (DIT) that has been widely used and has guided investigations on the acceptance and adoption of agricultural technologies is relevant for water resources management on smallholder irrigation schemes. The theory has been applied in many situations for the development of farmer decision-making models in the tropics for water resources management on smallholder irrigation schemes (Froebrich et al., 2018).

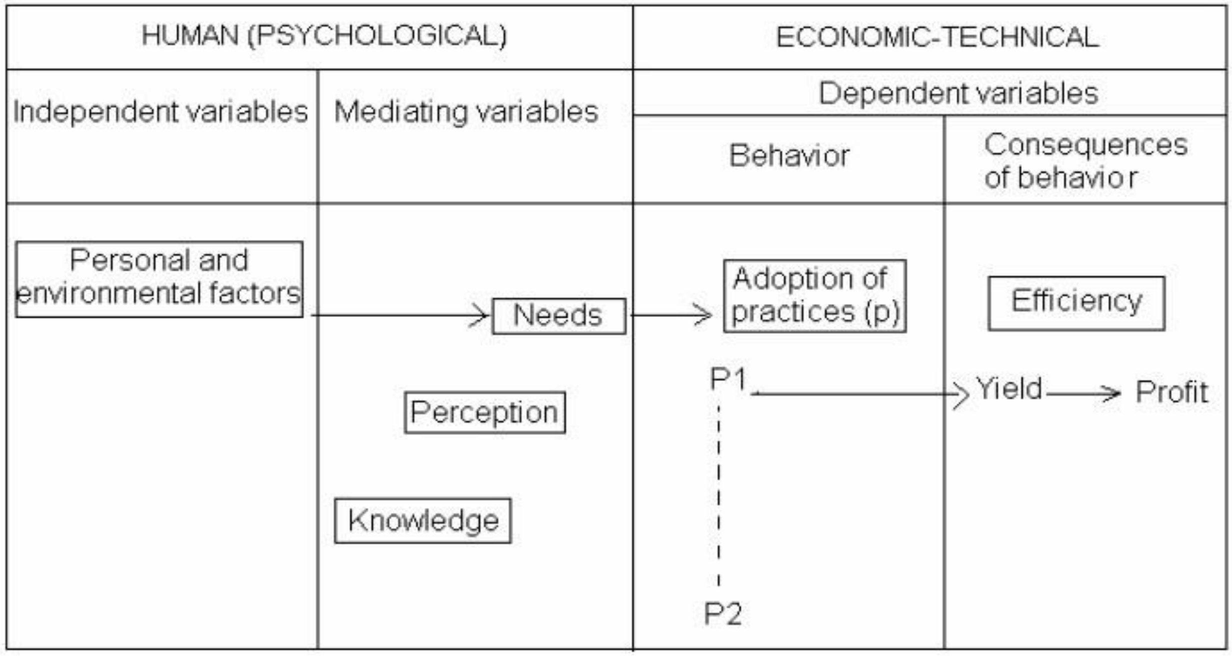
Soil and Water Resources Use Efficiency Management and Improvement

This section describes practices and strategies aimed at increasing the productive use of soil and water resources by reducing losses and optimising their use in irrigated farming systems. Soil infertility and water scarcity are among the factors that are of paramount concern, especially in Sub-Sahara Africa's drylands which affect only 25 percent of the global cropland area. Literature abounds that smallholder farmers can increase crop productivity in degraded soils, mainly drylands and areas with low carbon, by adopting soil and water resources management practices. Regarding soil infertility, for instance, incorporating trees (agroforestry) on farms that help capture nitrogen from the atmosphere can support restoring infertile soil and increase crop yields. Reducing water application in irrigated farming systems is another conduit that may boost crop yields and allow more time for other farming activities and household chores.

Over the past several years, independent variables such as socioeconomic, ecological and governance institutions have been extensively acknowledged and considered as factors of human adoption behaviours. Nevertheless, many adoption studies have discovered numerous discrepancies in connecting independent research variables to the adoption behaviours of people (Akudugu et al., 2012). It is recognised that human behaviour is crucially and necessarily variable and for that reason less predictable (Hatch et at. 2022). Because of the intricate nature of human behaviour various theories and models have been developed to appreciate adoption behaviour. Zhou et al. (2019) argued that the adoption and dissemination of new theories, technologies and algorithms are very important for accelerating innovation (p. 339). However, the diffusion process is multifarious and several theoretically unfamiliar issues can influence decisions to adopt such as independent and intervening variables. According to Düvel (1991), any adoption behaviour paradigm, to be acceptable, should make provisions for the effect of a wide number of dynamically reliant personal and environmental aspects, which depending on the condition can possibly become functional in several mixtures and directions. Duvel's model shows both the independent variables (personal and environmental factors) and intervening (mediating) variables. Among the intervening variables, he acknowledged needs, knowledge and perception to be important and argued that the effect of independent variables can be noted in decision-making based on individual's adoption behaviour through the intervening variables. The intervening variables are therefore deemed to be the most intrinsic and direct portents of the behaviour. Figure 2.7, therefore. shows a summary of several variables explaining the link between behaviour determining variables in a farming development setup. In this case, considering irrigated farming when water is scarce and yet a farmer would like to be food secure at household level.

Figure 2.7

Relationship between Human Behaviour Variables in Agricultural Development



Source: Duvel 1991.

Fertiliser Application Issues for Smallholder Irrigated Agriculture

When people talk about food security in Malawi, what they mean is to have adequate household maize productivity. Azeem et al. (2014) noted that maize (Zea mays L.) ranks third as the most important cereal crop after wheat and rice globally, whereas Malawi's farming systems rank first in importance (Jakobsen & Westengen, 2022; Kamanga, 2002). Dwindling soil fertility due to land degradation is one of the fundamental culprits of food insecurity among smallholder households in the country. On average, the soil loses nitrogen leaching more than 30 kg and Phosphorus 20 kg per hectare annually, particularly on arable land. Njoloma et al. (2016) claimed that land degradation remains the key contributing factor to deteriorating soil fertility exclusively in the smallholder farmers' fields. They further indicated that regardless of improved crop varieties availability, several research studies carried out in Sub-Saharan Africa generally and Malawi particularly have revealed that declining crop yields pose serious food security concerns at the smallholder farmers' household level.

In addition to other factors like climate change and variability, crop yields are being threatened by deteriorating soil fertility exclusively in the smallholder farmers' fields. So, continued soil fertility depletion is considered to be the main biophysical factor that can be responsible for reduced crop productivity if smallholder farmers cannot adopt modern farming technologies and the best agricultural practices. Fertiliser application to soil is one of the practices that farmers have adopted for increasing or sustaining crop productivity to meet the growing demand for household food security. Nitrogenous fertilisers have been noted to significantly improve crop yield (Habtegebrial et al., 2007). To enhance food security and reduce poverty, Malawi has implemented several programmes through hastened agriculture growth and expansion approaches under the Agriculture Sector Wide Approach (ASWAp) that offers smallholder farmers priority activities to increase crop productivity to end hunger, empower people to access healthy foods and intensify the agro-processing contribution to national economic growth (Daudi, 2010). No silver bullet has been identified to reduce food, land and greenhouse gas extenuation fissures or gaps in the world.

Considering water and nitrogen redistribution in the soil profile is, therefore, significant to enhance water and nutrient use efficiency for sustainable irrigated farming purposes. However, few strategies have been identified on how to develop a sustainable food security future that is required to be instantaneously used to reduce these gaps in Malawi. Fullstop a tool that has been introduced in Malawi for detecting nutrient redistribution in the soil profile is a positive issue for improving food security. Preserving satisfactory water levels within a root zone of a crop is vital because it influences the crop's capacity to absorb important soil nutrients, facilitates healthy root development, and eventually determines the general crop yield and quality (Liliane and Charles 2020). In this process, water acts as the solvent for the nutrients required for crop growth and operates within the soil. With insufficient water in the root zone, crops can experience stress, wilt and consequently reduce productivity.

Farmer Behaviours in Irrigated Farming

Farmer behaviours in irrigated farming facilities characteristically comprise of decision-making regarding water distribution, irrigation scheduling, soil fertility maintenance, crop selection, and the adoption of water-saving technologies. The behaviour of a farmer can heavily be influenced by issues such as availability and access to information, water availability, economic restraints, and social norms (Liu et al., 2018). These more often lead to practices that are efficient and sometimes not efficient depending on the situation.

Water shortage ascribed to CC and the unprecedented population growth is among the most relevant challenges the world is currently facing.(Fader et al., 2016). Constant increasing water demand is expected to intensify pressure on riverine ecosystems where smallholder irrigation systems operate from. Scholars and experts have indicated that irrigation scheduling, and smart agriculture using effective and efficient irrigation technologies at the farm plot level, along with basin management level and diversification of water sources, are valuable approaches to cope with the current CC scenario (Galioto et al. 2020; Rosegrant et al., 2009). Moreover, Aitken et al. (2016) claimed that using irrigation technologies can reduce scarcity by 19 percent.

To understand the motivations of smallholder farmers' decisions concerning the acceptance and adoption of water efficient technologies and farming practices is necessarily economic rationality, whereby the farmer is inspired by the objective of maximising his/her usefulness, subjected to a series of restrictions that may be linked to farm size, level of education, and financial resources (Handschuch & Wollni, 2016). Nevertheless, a farmer's decisions are entirely multifaceted than what economic rationality would specify, and they are also dependent upon cognitive and sociological variable. However, what is relevant is that productivity in smallholder irrigated farming facilities is central because it consents smallholder farmers to maximise yield per unit of crop water consumed, which is exclusively critical in areas with less water resources availability, contributing to food security while reducing water wastage and maximising the economic capability of the farm operations.

Social Norms and Cooperation

Social norms are values of personal behaviour that are based on extensively shared beliefs as to how individual group members ought to act in a given situation where human and economic variables play a very decisive role. According to Duvel (1991), the dependent factors are defined as the interventions that generally focus on the person's adoption behaviour regarding the suggested practice. The independent and dependent factors are considered as observable whereas the intervening issues cannot be apparent. According to Raworth (2018), it appears conceivable that social norms and cooperation can play a more vital role in water resources management since more interdependencies among smallholder farmers would happen in food system circles. Framers more often consider, feel and act one way when they know that they are being studied and different when they are not. Nevertheless, the biggest challenge of conducting a social and behavioural research study is the extraordinary complication of the investigation phenomena.

Dealing with human behaviours that influence one to adopt, there is, therefore, a need to make provision for a broad number of vibrant interdependent and environmental factors, depending on the context, which can become useful in many arrangements and directions. Based on a model developed by Duvel (1991), there are distinct provisions for independent variables (consisting of personal and environmental factors) and also intervening or mediating variables that are observed but are intrinsically relevant to the behaviour exhibited. Among the intervening variables Duvel developed, needs, knowledge and perception were acknowledged as influencing independent variables and are crucially manifested in decision-making for the adoption behaviour of individuals through these intervening variables. For human behaviour change, the intervening variables are recognised to be the most inherent and unswerving indicators (Zhong et al., 2019).

Water Availability and Its Use in Irrigated Farming

Population growth, migration, and changing lifestyles, the agricultural sector and food production systems are experiencing formidable difficulties and challenges (Juma et al., 2014). Considering issues that affect water availability and its utilisation are fundamental for evaluating and responding to these worries. This section surveys the theme of water availability and use related to irrigated farming production. Water availability for irrigation rests on the amount of water required by crops and how efficiently it is used, a measure of how well irrigation facilities perform (Tiruye et al., 2023). Due to CC, irrigated farming is increasingly experiencing new challenges that need improved water resources management and innovative strategy for its use. Previously, focus centred on project design; nevertheless, current issues consider exclusively limited water availability and supplies with several other competing users, water quality degradation threat through nonpoint sources (EPA, 2022) and narrow economic margins. To meet these challenges, it requires enhanced prediction of irrigation water requirements.

Agriculture Water Sources, Distribution, Use, and Likely Climate Change Influences

Conventionally, water resources for irrigated farming have been considered with respect to conjunctive water use, the coordinated management of surface water and groundwater, to maximise agricultural yield of the overall water resources utilisation. Besides considering surface and groundwater, accounting for rainfall and soil moisture, as they factor into hydrological and agricultural systems, Singh (2014) observed that sustainability of water resources is a crucial issue considering the relentless rising water demand for agriculture, manufacturing industry, and domestic uses globally.

Conjunctive water use is the harmonised management of surface and ground water resources that intends to maximise the yield of the overall water resources. A passive approach is to simply depend on surface water during wet periods and using groundwater resources during dry periods. To be managerially beneficial and lucrative both surface water and groundwater can be withdrawn in a coordinated way; where physically possible and positive these two resources can also be hydraulically interconnected (Cherepansky et al., 2009). They can also be expressively legal where the use of one source conserves the other for future. The beauty of conjunctive use of both resources is to meet water supply requirements.

The long-term sustainability of irrigated farming systems relies on the efficient management of available water resources. Besides, as these resources face greater demand that are driven by a widening range of applications and roles, the implications of water resources use will have profound influence on other sectors and the environment (Galioto et al. 2020; Nikolaou et al. 2020). By examining water availability for irrigation, it can lead to numerous implications, primarily including increased food production potential, but also substantial environmental anxieties, for example, water depletion, reduced downstream water availability, and possible environmental disturbances due to disrupted water flows and land use variations. While three percent of Earth's total water volume is recognised as fresh water resources, 96 percent is found in the form of ice in polar areas, and just one percent is simply accessible for human use and is mainly found in the physical forms of lakes, rivers, and tributaries where irrigated farming can be practiced.

Water Scarcity Concept

Another means for investigating water availability is the concept of water scarcity (Molden et al., 2007). Rather than examining water availability from a hydrological point of view, for instance, taking river basins as units of examination, water shortage emphasises on social and political areas considering populations as units of investigation. Estimating water scarcity commences at a micro-level, where individuals are determined to be water secure when they have consistent access to safe water satisfying their needs for drinking, washing, food productions, and other livelihood endeavours. On the other hand, individuals are water insecure when these requirements cannot be met. An area can, therefore, be water scarce when a large number of people cannot meet their objectives.

The water scarcity concept thus refers to a situation where the demand for water surpasses the available freshwater supply, meaning that there is not adequate water to meet the requirements of a population, most often because of a blend of aspects like weather variability, population increase, and poor water resources management practices. Water shortage can manifest as either physical scarcity. not sufficient water substantially available or economic insufficiency that determines lack of infrastructure that can access prevailing water sources. Water scarcity is a relative concept. comparing the amount of water that can be physically accessed with its supply and demand changes (J. Liu et al., 2017). Water scarcity intensifies as its demand rises and/or as water supply is affected by the decreasing quantity or quality

Water Use Efficiency Improvement

Irrigation is a vital agricultural component for food security in semiarid and arid areas that calls for efficient water utilisation and management. Much of the water used in irrigated farming is sourced from surface water bodies such as rivers, streams, and dams that are conveyed through open channels. Most smallholder farmers in developing countries use gravity-fed furrow irrigated farming as it is cheap, however too much water is applied (Mkuna and Wale, 2023). At best, furrow irrigation has a 60 percent water use efficiency.

Agricultural development in the past has generally been influenced by the area cultivated by a household rather than agronomic and water resources management improvement as observed by Hellerstein and Vilorio (2019). Irrigated farming depends heavily on the availability of water resources to provide an important contribution to the country's economy. The rising water demands with their consequent heightened water scarcity are expected to strengthen pressures on available water resources. With the erratic rainfall distribution due to climate variability and climate change, a technological intervention will drive and change the irrigated farming landscape that will increase water-use efficiency (Leal Filho et al., 2015; Waha et al., 2016).

The efficiency concept is to detect the nature of water loss and to decide the necessary improvements to be taken at the plot level. The term efficiency and what it stands for is very familiar to researchers and other people in different disciplines. Briefly, it concerns consuming less of some resource and the effect is that this is a moral issue to do. Nevertheless, this simple impression is not easily understood for irrigation water use and can produce distorted consequences. Water use efficiency or water productivity has evolved from the concepts of drought resistance and drought tolerance commonly described in agronomy as a ratio of crop economic yield to water consumed to produce the crop yield. Mathematically this can be represented as:

$$\textbf{Water use efficiency} = \frac{\textbf{Crop's economic yield}}{\textbf{water consumed to produce the requisite yield}} \qquad \textbf{Equation 2.1}$$

Thus, water use efficiency may be used at wide scopes. It may be used at the farmer's plot, plant, or specific plant parts levels. In this perspective, the aim of discussing the equation given above is to improve the utilisation of water resources to produce more economic crop yield with less water as is the case emerging in recent years. Equation 2.1 can be expressed in different ways but maintains the same logic of increasing water use efficiency. For example:

$$\textbf{Water use efficiency} = \frac{\textbf{Crop yield}}{\textbf{water use on the field}}\ (\textbf{kg ha}^{\textbf{1}}\textbf{cm}^{\textbf{1}}) \qquad \textbf{Equation 2.2}$$

$$\textbf{Water use efficiency} = \frac{\textbf{Total Biomass Yield}}{\textbf{Water use on the field}}\ (\textbf{kg ha}^{\textbf{1}}\textbf{cm}^{\textbf{1}}) \qquad \textbf{Equation 2.3}$$

$$\textbf{Water use efficiency} = \frac{\textbf{Total Cash Value}}{\textbf{Water use on the field}}\ (\$\textbf{m}^{-\textbf{3}}) \qquad \textbf{Equation 2.4}$$

Equations 2.2 and 2.3 are relevant for sole cropping whereas Equation 2.4 is suitable for multiple cropping based on limiting water supply conditions. These equations show how water use efficiency can be increased in both rain-fed and irrigated farming mainly in sub-Saharan Africa where crop productivity is affected by poor soil nutrients and low water application (Tsujimoto et al., 2019). The essence of increasing water use efficiency is to save water resources. Water-saving is a concept that describes a recipe of agronomic, physiological, genetic, and engineering strategies to reduce crop water use. Numerous reports have focused their attention on reducing water use for irrigation in hot dry environments because in these environments crops need high water use as a result of high crop evapotranspiration rates as well as in drought-prone areas (Bodner et al., 2015; García et al., 2020; Rey et al., 2017; Putnam, 2015).

Increasing water use efficiency and how effectively crop revenue can be increased with available water resources is another issue that needs thorough consideration. Nonetheless, the key approach that is required to be implemented on SIS to increase water productivity is better for water resources management and using water efficiently not because water is in short supply but also to sustain and protect the environment from deterioration and pollution (Cosgrove and Loucks, 2015). Smallholder farmers are required to be inspired to increase water productivity through technical assistance, farmer training, requisite incentives, and suitable policies. Improving water productivity depends not only on water management, however, it includes a broad range of farming practices

It is evident that with climate change and variability, water availability on irrigation schemes is expected to cause conflicts as there shall be water shortage and insufficient distribution and supply on irrigation schemes. For instance, in the tropics where the climate is warmer, more water evaporates from both land and crop leaf surfaces contributing to a warmer atmosphere that holds more water. As the water supply is reduced conflicts are common occurrences due to differences over access or use of water resources that lead to violence between and among interested individuals and/or groups. Thus, the climate is a key issue in water governance, particularly in supply planning. Goosse (2015) described the climate as the aggregate of weather conditions representing the changing characteristics of the atmosphere-hydrosphere-land surface climate system over the earth. Climate fluctuates over time in any one geographical location and also differs from one geographical zone to another.

As climate change and variability are causing a tremendous menace to humanity and the environment at large, irrigation as already noted is an alternative source from which people can improve their livelihoods. However, irrigation requirements are also defined by climate as well as crop and soil characteristics. Differences in evapotranspiration rates of crops are a result of differences in canopy resistance and the proportion of green ground cover. Despite considerable efforts that have been made to enhance crop production and environmental conditions in many emerging nations, particularly in Sub-Saharan Africa, many smallholder households continue to experience poverty, food insecurity, and decent living in areas where they have traditionally relied on rain-fed agriculture as the main agricultural activity (Wani et al., 2009). Water use efficiency or water productivity has evolved from the concepts of drought resistance and drought tolerance. Water use efficiency has been commonly described in agronomy as a ratio of crop economic yield to water consumed to produce the crop yield. Mathematically this can be represented as:

$$\textbf{Water use efficiency} = \frac{\textbf{Crop's economic yield}}{\textbf{water consumed to produce the requisite yield}} \qquad \textbf{Equation 2.5}$$

Thus, water use efficiency may be used at wide scopes. It may be used at the farmer's plot, plant, or specific plant parts levels. In this perspective, the aim of discussing the equation given above is to improve the utilisation of water resources to produce more economic crop yield with less water as is the case emerging in recent years. Equation 21 can be expressed in different ways but maintains the same logic of increasing water use efficiency. Whereas. Equations 2.2 and 2.3 are relevant for sole cropping whereas Equation 2.4 is suitable for multiple cropping based on limiting water supply conditions. These equations show how water use efficiency can be increased in both rain-fed and irrigated farming mainly in sub-Saharan Africa where crop productivity is affected by both poor soil nutrients and low water application (Tsujimoto et al., 2019). The economic crop yield, therefore, explains the measurement, quantity or weight per unit area of only those crop components that have marketable value against the water consumed to produce the required yield.

Integrated Watershed Management

Generally speaking, the water sector in certain contexts is likely to fulfil some social, environmental and economic requirements. In circumstances where there is a growing concern of water scarcity exacerbated by unprecedented population growth, poor allocation of resources, environmental degradation, and mismanagement of natural resources, smallholder farmers on irrigation schemes face enormous challenges that call for a paradigmatic shift to natural and water resources management (Tal, 2016).

Water consumption through industrial, domestic and agricultural use has grown tremendously during the past century. While there is not yet a global water deficiency, nearly 3.0 billion people, representing slightly over 40 percent of the global population, reside in river basins where some form of water scarcity has been reported. However, Kummu et al. (2016) claimed that about 1.2 billion people lived under physical water scarcity. This among others underscores some of the challenges faced by many countries in their quest for economic and social development. Flood effects, quality deterioration and water scarcity are among the challenges and problems that require greater and swift attention and action.

The demand pressed on water resources highlights the environmental, hydrological, social, and economic inter-dependencies in river, lake and aquifer systems. These interdependencies necessitate more integrated approaches to utilising and managing water and land resources. There is an active connection between watershed stakeholders and governments to work together to ensure that their decisions in water abstraction in meeting their objectives should be based on sustainable development goals. Based on the judicious use of water resources on a watershed vis-à-vis catchment basis, the International Conference on Water and the Environment held in Dublin in 1992, formulated four guiding values associated with water use. These values are briefly discussed below.

Value No. 1: Freshwater is a limited and susceptible resource. It sustains and is vital for life, development and the total environment. Since water is life, its effective management demands a holistic approach that connects social and economic development through natural ecosystem protection. Effective water resources management importantly connects land and users across the catchment area. Vannevel and Goethals (2020) argued that there is an increasing agreement that sustainable development needs behavioural change underpinned by a strong decision-making process. Yet, prevailing decision-supporting tools are doubtful to offer the relevant information as they are hindered by the complexity of mutual socio-economic and natural systems. Thus, guarding the inherent value of ecosystems and providing adequate natural resources for human use instantly may lead to a wide range of management, from species traits to governance.

Value No. 2: Water resources management and development should follow a collective action approach that includes users, planners, policymakers and other stakeholders at all levels. This approach comprises creating awareness of the significance of water resources between policymakers and the general public requiring that decisions start from the lowest fitting level, with full public consultation and involvement of users in the planning and implementation of water supply projects (Wehn et al., 2018; Tengberg and Valencia, 2017).

Value No. 3: Women play a key role in the delivery, management and protection of water. This is a vital role for women as providers and users of water and guardians of the active environment have hardly been considered in institutional programme items for water resources development and management. Acceptance and implementation of this value, therefore, need constructive policies to address the specific needs of women. More importantly to equip and empower them to participate at all levels in water resources programmes, including decision-making and its implementation, in ways that are suitable for them.

Value No 4: Water is an economic resource in all its contending uses and must be known as an economic good. Based on this principle, it is important to acknowledge first the fundamental right of all people to have access to clean and quality water at a reasonable cost. Past failures to acknowledge the economic value of water influenced lavish and ecologically harmful uses of the resource. Thus, handling water as an economic good is an imperative way of achieving resourceful and impartial use, as well as inspiring the conservation and protection of water resources. These values have been formulated with the idea of addressing the complex nature of water management. As a consequence, several countries have embarked on an integrated approach to water resources management ranging from the national to the catchment level (Mehta et al., 2016; Van Koppen et al., 2017). This includes improving institutional arrangements and working practices focusing on effective and efficient application of integrated water resources management approach along lake, river and stream basins.

Integrated Water Resources Management

Integrated water resources management (IWRM) is a procedure whose aims are to manage water, land, and related resources in a well-coordinated means to maximise economic and social wellbeing while safeguarding the sustainability of significant ecosystems by considering the requirements of all stakeholders and ranking equitable access to water resources across diverse sectors. It is necessarily a holistic approach influencing water resources management through balancing social, economic, and environmental reflections. IWRM is basically a governance issue as it entails harmonized management of water resources across diverse sectors and stakeholders. Governance in this study defines the way authority is systematised and executed in a irrigated farming systems, and more frequently includes the normative belief and understanding of the need for equitable water distribution (Palerm-Viqueira, 2009). The Global Water Partnership (GWP), however, defines water governance as the variety of political, social, and economic administrative structures that are organised to manage water resources and distribute water to different levels of society (P. Rogers & Hall, 2003). Governance is a broad term that includes institutions, organisations, and policies.

The integrated water resources management approach is conceived to help in the development and management of water resources in a sustainable and balanced that considers social, economic and environmental interests. Besides, recognising the many diverse and competing interest groups within the sectors that use and abuse water, and also realise the environmental needs. The integrated approach essentially coordinates water resources management across the sectors and interest groups, spanning different levels and scopes, from global to local basin levels. It underscores people's involvement who are affected in national policy formulation processes that help to create good governance and effective institutional and regulatory measures as conduits to more reasonable and justifiable decisions. A range of tools, like social and environmental appraisals, economic devices, information and monitoring systems, support this process. In all these efforts, it is the behaviour of users that is important and requires thorough understanding (Mundial, 2019).

Theoretical and Conceptual Framework

Theoretical and conceptual frameworks for a research study are constructed not found. They contain ideas that are derived from other studies, but then the structure and their overall rationality are built by considering the problems and challenges that require to be circumvented through the investigations to be conducted and not that they already exist and are ready-made (Davies et al., 2015; Larsson and Teigland, 2019). Yet, they offer the processes and ways to be performed by the researcher during field surveys so that the constructs are decisively grounded.

A theoretical framework can be explained as a plan or guide for conducting research. A theoretical framework is founded on current theory in an area the research is premised that relates to and/or reflects the hypothesis of a study. It is a blueprint that is often used in constructing modalities of research inquiry. It serves as the foundation upon which research can be constructed. Researchers have compared the function of the theoretical framework to that of a roadmap or travel plan. (Tamene, 2016). Thus, the theoretical framework for the research work is based on two theories.

The first is the Theory of Change which concerns the methodology for preparation, involvement, and assessment in promoting social change. It is an approach that describes how a certain method, or suite of methods, are likely to lead to a particular development change, drawing on the underlying analyses based on prevailing evidence. It defines long-term aspirations and then traverses backwards to recognise required prerequisites. Thus, it is a theory-driven method that helps in designing and appraising complex interventions (Maharjan and Maharjan, 2017). The second is the Firm Theory which states that a firm is created for the production of products required by customers and as such makes decisions to maximise profits. Technological change from an archaic technology is a further source of yield growth as it involves an upward shift of the production function, implying that the utilisation of advanced technology can produce more output for each level of input (Lafuente et al., 2020). These theories of change offer easy explanations of complexity in reality and worldview. They help to formulate clear, robust and testable hypotheses concerning how change may occur that not only agree to be accountable for results, but also ensures the results are more credible because they were predicted to happen in a certain way. Ultimately, they provide a structured framework that clearly articulates how a study intends to achieve its desired outcomes.

A conceptual framework can briefly be defined as a demonstration of the interactions a researcher is expected to see between and among the variables or the characteristics or properties under study. It is written to link all pertinent variables to be investigated and is largely developed based on a literature review of a research topic (Flick, 2018). Consequently, researching "assessing water productivity and profitability through farmer learning in selected SIS in Malawi" offers a vital chance to conceptualise and concretise pathways that can be used to improve water productivity and profitability issues that are pertinent due to climate change (Nhamo et al., 2016).

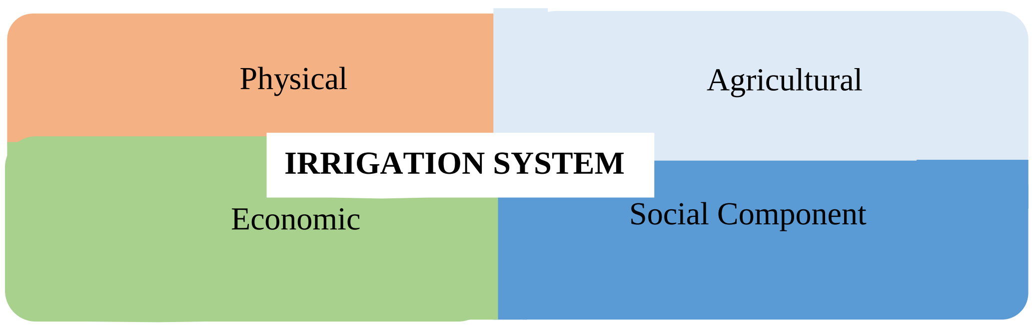
A conceptual framework emphasises the reasons a research study is undertaken, its significance, relevance and period, including data assembly and analytical procedures, suitably and rigorously answering the formulated research questions (Kabir, 2016). Moreover, it is a precise examination of characteristics that have been identified and explained in the theoretical framework and are used to formulate research hypotheses. It is in other words, a tentative theory of the phenomenon to be investigated. It is a diagnostic instrument with several distinctions and contexts. Its function is to enlighten how the research design would be and how it supports assessing and filtering research aims to articulate characteristic and pertinent research questions and choose proper approaches and methods (Tamene, 2016). Besides, it can be used in various sets of research work where a complete picture is looked for.

The main purpose of these two frameworks is to determine how the research outcomes are more meaningful and relevant to those affected. Thus, both the theoretical and conceptual frameworks instil life into a research investigation (Long et al., 2018; Vinz, 2015). However, before proceeding it is important to answer the questions: "What is a Theoretical Framework?"

and “What is a Conceptual Framework?" Conversely, before descriptions of these frameworks are presented, it is relevant that the term 'theory' be looked into first to understand and appreciate its position in research. It is noted that an irrigation system should comprise physical, agricultural, economic, and social components as shown in Figure 2.8.

Figure 2.8

Irrigation system components



According to Arnold et al. (2017), human communities' modification of important environmental processes and structures is the vital category of change driver as water shortage determines how people use and access the available water resources. Lack or shortage of water resources has a huge impact on the conditions of ecosystems like irrigation schemes. The ecosystem conditions and services are compromised in which productivity is notably reduced affecting people. Therefore, governance, a vital factor in the social justice, use and sustainability of natural resources, is a vital attribute in farmer learning. Thus, a smallholder irrigated farming facility can be perceived through physical, agricultural, economic, and social lens as each component plays a decisive role in the general functionality and sustainability of the system.

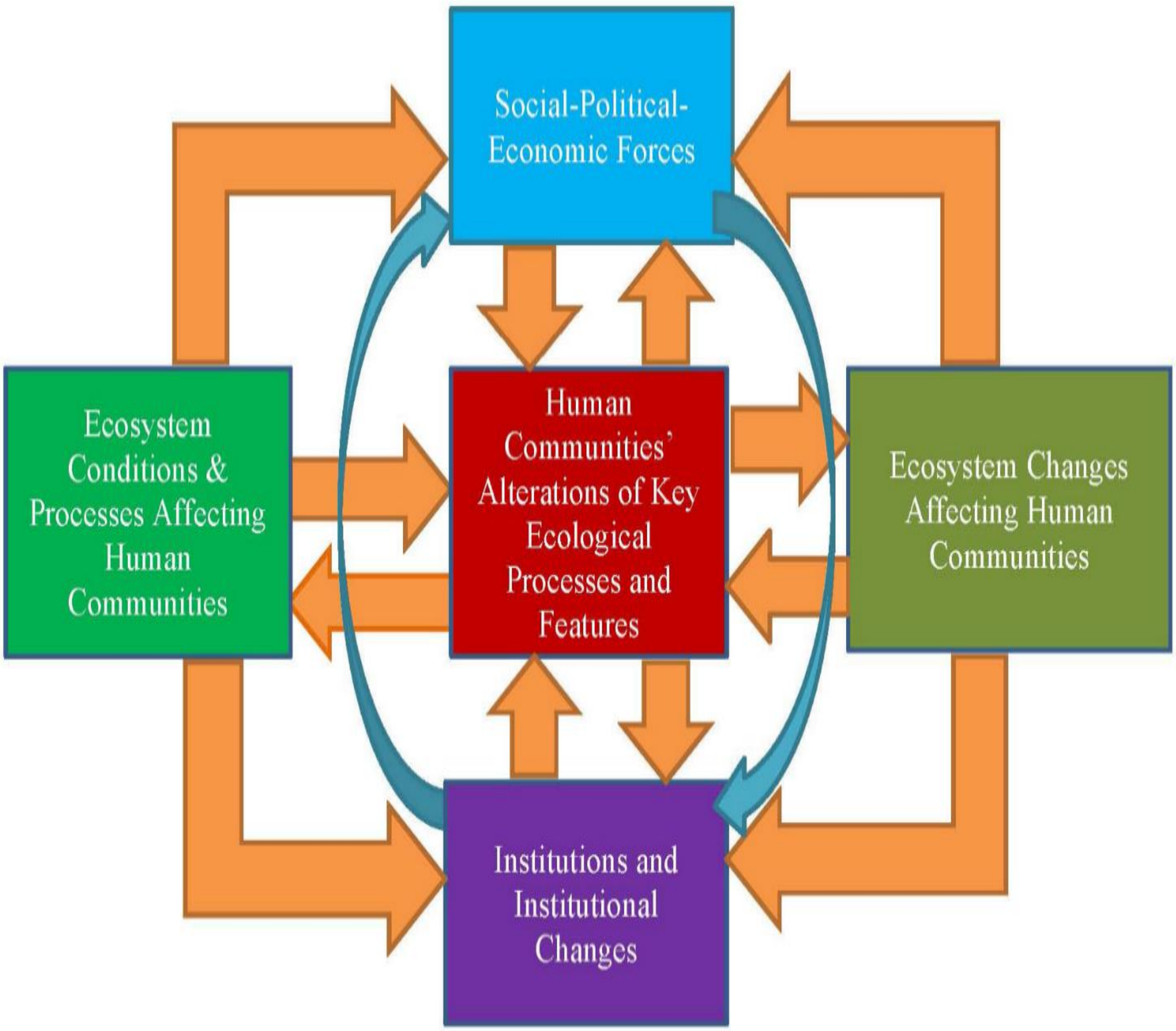
The influencing factors such as water availability and accessibility, farmer livelihoods, as well as community dynamics within an irrigated area can be known through the lens (Touch et al., 2024). As smallholder farmers are a diverse and dynamic grouping, circumnavigating complex environments where multiple factors intersect particularly in irrigated farming systems, they need to be knowledgeable and conversant with irrigation systems at their disposal. This is because farmers more frequently are found to be confronted with a variety of challenges, however concerns regarding soil water availability is of utmost importance (Serku, 2023). Currently, biodiversity and ecosystem services models assess anthropogenic stressors for example, climate and land-use changes applying circumstances that function separately (Rosa et al., 2020). Socioeconomic variables forecast like population analysis and land-use change have been customarily utilised to estimate effects on biodiversity distinctly from those on ecosystem services (Estrada 2013; Li et al., 2020).

Appraisal of Irrigation Systems Performances

An appraisal of irrigation system performance entails estimating the adequacy, efficiency, and uniformity of a n irrigated farming system through quantifying key parameters like water delivery at plot level, water application efficiency, and uniformity of water distribution across the farmer's plot (Sibale et al., 2021). These parameters depend on factors like irrigation systems design, operation, infrastructure maintenance, and environmental effects to classify areas for enhancement thereby optimising water resources use and practices. The purpose of an appraisal is to accomplish an efficient and effective use of water resources in irrigated farming systems by providing appropriate feedback to the scheme management at all levels. According to Mateos et al. (2018) three types of performance measures can be employed: process, output and effect measures. The first type describes the system's internal processes like policies, structural and communicative processes. The second type is used to assess services provided to farmers that are of vital importance given its influence on crop productivity and profitability in terms of system's final output. The last type appraises the system influences on social, economic and environmental dimensions. Figure 2.9 shows the forces of altering biodiversity levels on ecosystem function and represents the main groups of modification drivers and their relationships. It can be noted that the robust effect of ecosystem conditions is represented on both the left and right sides of Figure 2,9 with the human behaviour at the centre.

Figure 2.9

A framework of influencers of ecosystem change.



Source: Arnold et al. (2017).

While the research aims to assess water productivity and profitability through learning and the interaction of smallholder farmer with their peers in the irrigated farming systems, who are directly associated with their farmers' interest. The emphasis is therefore placed on both process and output measures, with the overarching objective of realising a deep understanding of the system's performance conducted by farmers at different dimensions of water resources use and management. Out from these, several pointers can be used to assess the irrigation system performance, being complemented by pointers of social, agronomic. technical and economic nature, aiming to evaluate accurately the interface between the irrigated farming facility and the agricultural enterprise (Giordano, Namara, et al., 2019). Certainly, a precise description of this interface appears to be of notable position when appraising certain irrigation system performance. The link between an irrigation facility and agricultural practices becomes apparent in practice when scrutinising the effect of waterlogging and drainage systems in reducing salinity as well as considering water shortage for the choice of crops that will be planted.

Traditionally, irrigation scheme appraisals have been carried out mostly from a technical viewpoint, based on hydraulic and agronomic principles according to Bos et al. 2(005). This technical method is classically a top-down approach, given its logical nature of systems investigation by separating into diverse sub-systems. From a water distribution perspective, shared water management experiences diverse challenges and problems in different parts of the systems, which determines the technical robust role in the development of irrigation facilities (Mahdi, 2024). Accordingly, soil water balance has been at the centre of the scheme assessment performances, concentrating crucially in water delivery efficiency in irrigation facilities for increased water productivity (Cheng et al., 2023). Additionally, efficiency of water conveyance has been extensively investigated that helped in developing indicators to examine truthfully water supply distribution and field application to abate water losses and enhance its use. Other features of irrigation like technical actions or system maintenance have been commented by experts to improve overall irrigation systems performance.

Policy Formulation for Irrigation Development

Policies are always advocated when it comes to irrigation development. But what is a policy? Simply, a policy is a prescribed process or method for taking action to attain a specific goal. Policy formulation varies on a wide range of issues whether it can be economic, social, cultural or governance. Nevertheless, a policy does not traverse as a linear process consisting of a series of steps, but rather it revolves around an iterative process through commuting between stakeholders. The policy formulation process is iterative that goes to and from between those making decisions, end-users, opinion leaders and interested parties. This is done to break down issues into specific items to be well scrutinised and analysed to successfully attain the policy goals. Policy instruments are usually combined to create a pathway to reach these goals and this process is called policy instruments. However, according to Bouwma et al. (2015), instrument selection should reflect basic principles and recapitulate the influence of the instrument to be used. The measured instrument approval should be always broad; however, they should also allow for externalities.

While the major concern of decision-makers in irrigation and water management may be mainly on water use efficiency, taking an all-inclusive perception of water as a natural and threatened economic resource can also be predicated. Without factoring in a wide range of stakeholders and environmental interests, any efficiency improvements may be temporary and prove administratively unfeasible in the long term. Nevertheless, the main objectives of irrigation and water management policies include:

Encouraging and promoting unbiased and fair access to irrigation development through equitable water distribution. The second objective is to guarantee the sustainability of SIS and water management systems. Lastly but not the least is to increase water use efficiency. This does not only consider technical efficiency in water conveyance and application but also economic efficiency, the net value returns to farmers and the value of the irrigation system to the society as a whole, considering externalities and alternative water uses. To achieve all these objectives, a deliberate policy can be promulgated that may essentially propel investment in irrigated farming (Odutola 2020).

Influence of Policy to Improve Water Use Efficiency

It is well established that the agriculture sector has a poverty-reducing influence such that elegant agricultural packages have numerous outcomes for livelihoods. Some of the outcomes that easily be highlighted are improving household food security, improved revenues, and rural employment. According to Nechifor and Winning (2018), irrigation is central to boosting crop production and productivity that can gradually transmute subsistence-driven to lucrative commercial-propelled farming systems. Its pro-poor bearing is principally important when irrigation schemes are part of the national economic development in which smallholder farmers with limited landholding sizes and resources improve their production. Besides, well-crafted policies are essential to underpin smallholder farmers' hard work that is consistent with sustainability and economic objectives as argued by Ansah et al. (2020) and Moyo et al. (2017).

Based on the lessons from the Green Revolution, it can be said that considerable investment will be needed in irrigated agriculture to develop nearly 172 million hectares of irrigation-equipped area by 2050 (Bernard and Lux, 2017; Morone et al., 2019; van Loon et al., 2019; Tamburino et al., 2020). Irrigated farming development mainly in developing countries requires cautious analysis to be successful to moderate failures and frustrations and maximise values and profits. In this respect, the approach to plan for irrigation policy formulation should be grounded on increasing efficiency and effectiveness. The key issue is participatory management through which irrigation scheme operation should be the responsibility of smallholder farmers themselves. In this case, there should be an equal distribution of responsibilities among users. This may, therefore, bring environmentally sound management that is designed inclusively and institutions well developed as vivid proof of the efforts in improving irrigated farming (Gohar et al., 2015).

It has been reported by many experts concerning the underperformance of small-scale irrigation systems. The issues that have been highlighted include substantial water losses through conveyance as canals are not repaired and maintained. Framers fail to control the flow of water and there are enormous challenges in water distribution among users. These are the most common problems that are experienced by both farmers and scheme managers. Based on this, it is relevant that policies should be formulated to strengthen water use efficiency and productivity at the smallholder irrigation scheme level.

The long-term vision is to improve crop production, and productivity and eventually increase household incomes (Kassam et al., 2019; Pék et al., 2019). This eventually leads to an increase in investment in agricultural water resources management that is socially unbiased, economically viable, environmentally sound, sustainable, and lucrative at the farm level. The policies formulated should focus much on specific constituents of improving water use efficiency on smallholder irrigation schemes while making and applying relevant water use efficiency measures at the field level (Kimaro, 2019; Makin, 2016; Pittock et al., 2018). It is acknowledged that improvement in irrigation performance should be grounded on good governance.

The renewed importance concerning irrigated farming coincides with a mounting acknowledgement that investing and providing irrigation services is not purely a technical engineering issue but also concerns addressing the intricate interaction of numerous disciplines. Experts have studied and assessed how perceptions of irrigation systems and services have progressed over the past half-century from a comparative engineering issue to simple water monitoring tools that less-educated farmers may use (García et al., 2020; Loucks and van Beek, 2017).

For investments to perform considerably well regarding new irrigation systems or rehabilitating and reforming current irrigation schemes, it is imperative to appreciate and encourage how the irrigated agricultural sector can perform practically, and how water delivery services and change processes on irrigation schemes should be formed not only by considering the biophysical limitations but also by social and cultural thoughts. Focusing on the interests, observations, and plans of policy actors like politicians, irrigation bureaucrats, and farmers regarding defined policies and how they reshape negotiation processes, resource distributions and the creation of alliances in the policy processes are decisive in unpacking the existing power relationships shape outcomes. To achieve all these, a deliberate policy can be promulgated that essentially propels investment in irrigated farming (Odutola, 2020). Thus, it can promote an approach to sustainable and equitable development requiring well-informed, purposeful courses of action by the government and stakeholders.

Potential Changes in Water-Use Efficiency

To understand water-use efficiency, it is important to examine this concept of water use by crops happening at different levels of crop development from the leaf to the canopy levels. Considering situations happening at the leaf level, water use is controlled by energy availability from the sun impinging on the leaf where a vapour pressure deficit arises and an aerodynamic exchange develops but is controlled by stomatal conductance (Hatfield and Dold, 2019). Whereas at the canopy level, the processes are different as it involves the energy exchange at the soil surface and the plant canopy where water loss is a combination of evaporation and transpiration from the soil surface and the plant canopy respectively. This combination of evaporation and transpiration is expressed as evapotranspiration. Literature regarding crop water-use efficiency and extensive use of crop water use is used as the metric for water-use efficiency (Mubeen et al., 2019). It is important to realise that these specific terms need to be wisely assessed when inferring the results obtained from different investigations or research studies or comparing the studies.

Looking at what is happening in potential areas where irrigation can be implemented, Perry et al. (2017) depicted a picture that water resources use had approached its full development. This can be amplified by basing it on continued migration to urban areas which is increasing unprecedented pressure on two fronts: domestic water supplies and an increasing need to protect, preserve and restore environmental flows. In this respect, it can be observed that there is limited scope for further expansion of irrigation unless innovative ideas can be floated for discussions (Andrea 2015; Callway et al., 2019). One such topic is to promote simple soil water monitoring tools so that illiterate farmers can be able to interpret their meanings (Jiang et al., 2015). Changing the way water is applied in irrigation schemes can be the key to the well-being of smallholder farmers in Malawi (Phiri et al., 2012). Irrigated farming has the potential to transform food insecurity and poverty in Sub-Saharan Africa.

Conduits to Meet Improved Crop Productivity

Crop productivity increment is indispensable to keep up with household food demand. Researchers have and continue breeding higher crop-yielding varieties whose selection of best-performing crops is based on better genetic traits that have contributed around 50 percent of historical crop yield improvements. With a projected nine billion people on this planet by 2050 and average earnings that are on the rise, particularly in emerging nations, balancing future household food demand will be an enormous challenge and insurmountable task (Qaim, 2020; Lenaerts et al., 2019). Migration to cities, land degradation, climate change and variability, are driving further pressure on crop production. There are new avenues to surmount these challenges through molecular biology perceived to offer great promise for surplus crop yield gains by developing crop varieties that mature faster via mapping the genetic codes of plants and testing their desired DNA traits to purify crop strains that can turn genes on and off thereby providing bumper crop harvests (Zaidi et al., 2020; Bailey-Serres et al., 2019; Abdallah et al., 2015).

Irrigation Scheduling

For effective crop productivity and water resources management, both sequential and area distribution of irrigation supply is imperative. Suitable and timely water supply with the required quantity or volume is allocated and done by implementing irrigation scheduling programmes in irrigation schemes. Irrigation scheduling is the process of deciding the time to irrigate and water volume to apply, necessarily based on measurements or estimates of soil water content available in the root zone or water used by the plant (Pereira et al., 2021; Ewaid et al., 2019; ASABE, 2007). Irrigation scheduling is determined by water requirements by crops. Crop water requirements are the depth of water in millimetres necessary to meet water consumed by a disease-free crop via evapotranspiration growing in an expansive area under non-restricting soil conditions including soil water and fertility, with these conditions, a full crop production potential can be achieved.

The determination of soil water content can be done by using tensiometers that educated people mainly irrigation engineers can calculate water availability in the soil. However user-friendly tools are now available that illiterate people can understand and act when colour codes are displayed on devices like a chameleon (Mdemu et al., 2020). In summary, irrigation scheduling is a practice of water management that considers the timing and regulating water applications in such a manner that the applied water will satisfy crop water needs without wasting water, soil, plant nutrients, and/or energy. Therefore, appreciating how farmers use water resources and their potential effects is essential for the development of sustainable water resources management options. When farmers need water for their fields, there is a process where areas are informed when water will be delivered or supplied. This water delivery process is referred to as irrigation scheduling which determines the volume and time to supply it for irrigation. Irrigation scheduling has a direct influence on water use efficiency. It is noted that applying too much water than is required for optimal crop consumption decreases the irrigation water use efficiency. Thus, irrigation scheduling needs an appreciation and an understanding of the way plants use water affected by such factors as weather, growth stage and canopy wetness.

It is noted that water application may be planned based on the crop water status, which may be measured directly using tensiometers, or indirectly by monitoring the colour differences on simple devices. Other indirect methods comprise soil water content determination using soil probes and crop water evapotranspiration estimation. However, some of the key challenges of using these soil-moisture-based tools for water application is that they give point-based information, while the soil qualities are known to vary spatially and temporally (Soulis et al, 2015). It has been known for a long time that many smallholder farmers depend on their experiences by using a rule-of-thumb, without using any scheduling tool, and frequently lose or misuse water. To improve this situation, there are currently emerging approaches to measuring soil water status to inform farmers when and how much water to apply to their fields. With current technological development in irrigated farming, farmer-friendly tools can be used to help in the decision-making process to schedule water applications. Characteristic examples of these include chameleon and waterfront detectors (Ncube et al., 2018; Stirzaker et al., 2017). These devices are cheaper and more versatile and have been proven to be friendly as colours and pop-ups are indicators that illiterate farmers can be conversant with.

Knowledge gap

Through the literature review, this study identified some gaps related to water resources management and water use. This section, therefore, focuses on the information and knowledge gaps that have either partially been explored or not yet considered or are under-explored. The study reviewed several SIS in different countries particularly in Africa and the Mediterranean, and checked on various empirical findings on water resources management smallholder irrigation scheme performance and water resources management. Identifying knowledge gaps for research is decisive because they underline areas where knowledge, information and/or understanding are lacking, allowing researchers to focus their efforts on attaining the essential knowledge to enhance decision-making, achieve goals and performance.

A significant knowledge gap prevails regarding irrigated farming particularly in areas for example optimal water resources management practices, understanding soil water content, suitable irrigation system maintenance, crop choice appropriate for irrigated farming, soil fertility maintenance and adjusting to changing water availability The gaps often arise from lack of knowledge and inadequate access to relevant information, favourable training, and absence of practical competencies required to effectively operate irrigation facilities for maximising crop yields while lessening water wastage.

Key characteristics of this knowledge gap comprise smallholder farmers lack of knowledge on choosing appropriate irrigation technology for their land and crops, appreciating water shortage, and detecting likely facility malfunctions; water scheduling and monitoring have been identified to be challenging in accurately regulating the right amount of water required for different growth stages of crops, and not knowing how to monitor soil moisture levels to avoid overwatering or underwatering, there is limited understanding of how climate change influences water availability and how to regulate irrigation practices accordingly, scarce availability of trained extension delivery staff who can disseminate accurate knowledge, targeted information and offering support to smallholder farmers on water application and modern farming practices. Exclusively, there is low literacy levels among smallholder farmers that influence much difficulties in accessing and understanding complex technical information associated with irrigated farming more so they rely on traditional farming practices that are archaic and not compatible with modern irrigation systems. Cost of technology has been acknowledged as one of the barriers to adopting innovative irrigation technologies and lack of financing opportunities. Thus, to bridge the knowledge gap farmer training programmes are must that provide hands-on demonstrations about suitable irrigation management practices. This action will facilitate knowledge sharing among smallholder farmers through farmer-to-farmer interaction as a community-based learning initiative. Moreover, increasing and strengthening extension staff capacity with rationalised knowledge on irrigation technologies and effective outreach strategies have been identified as crucial to improving crop productivity and profitability and this research intended to identify causes of low crop yields and unprofitability of irrigated farming.

The mediating influence of operational scheme management on the relationship between irrigated farming performance and household food security, as well as the relationship between water shortage and water use efficiency, is currently established and widely recognised (Pan et al., 2017). In order to improve water productivity and household profitability, water use efficiency, a measure of how resourcefully crops utilise water to produce yield is important for smallholder farmer to suitably conserve water within the rootzone. Intensifying water use efficiency has a considerable effect on long-term smallholder agricultural production, profitable growth, crop productivity and food security. The literature review has identified agricultural water management pathways as conduits for solving poverty reduction among smallholder farmers spearheaded by institutional structures agreeing well with what Wijana and Setiawina, (2021) elucidated about farmer welfare improvement. The goal of this study is to close the prevailing knowledge gap in water resources management. The role of farmer learning in mediating the relationship between water resources management practices and crop productivity, as well as social behaviour in moderating the relationship between water resource use and conflict resolution, has experimentally been demonstrated and understood (Ataei et al., 2022; Coulibaly et al., 2021).

Nonetheless, the omitted piece in the water resources management knowledge pack is the extent to which smallholder farmers can adequately apply water on their plots so that water benefits the crops and soil nutrients are not excessively leached out of the root zone. To make an important impact on crop productivity and profitably there is a knowledge gap prevailing within the uneducated farmers as to how they can successfully and adequately apply water on their plots as water shortage is the order of the day.

The purpose of this research was to fill in the gaps by addressing the question, “What difficulties and challenges hinder the transfer of modern irrigated farming technologies from the perspective of smallholder farmers in Malawi? The identified gaps that are in consonance with the objectives of this research are that farmers' lack of knowledge and practices in water application techniques and modern irrigated farming that have a bearing on water resources use. It has also been noted that smallholder farmers’ choice of growing lucrative crops and water resources use are affected by behavioural characteristics. For them to know whether they are applying water appropriately, presence of a shared metric that detects factors influencing crop water consumption is a necessity across different schemes, farmer categories and age groups.

Summary

The global development system contemplates that food security is realised when all manner of people, always, have physical and economic access to adequate, harmless and nutritious food that meets human dietary needs and food predilections for a lively, vibrant and healthy life (Calabi-Floody et al., 2018). Incidentally, the capacity of smallholder households to access food through high crop production, acquisition or transfers becomes imperative in explaining household food security and poverty. For any research in whatever discipline, theoretical and conceptual frameworks are required that justify the research study and describe its structure. A theoretical framework explains the key ideas and perceptions of the research. It suggests relationships between/among the ideas and examines applicable theories based on a literature review as Kivunja (2018) alleged. A robust theoretical context provides the research with its direction allowing it to persuasively interpret, explain and simplify issues from the research findings.

CHAPTER 3: RESEARCH METHODOLOGY

Introduction

This chapter provides an overview of an approach adopted for the research study. It identifies the research's epistemology and theoretical perception. It further explains the research methodology and approach adopted to achieve the formulated objectives. It should be pointed out that there is not one suitable way to carry out research; there are numerous methodological choices a researcher may consider taking, and the choice made can influence the knowledge gained from the study conduct (Fleming, 2018; Fleming and Zegwaard, 2018). As such, this study is conducted within a pragmatist philosophical paradigm mindset and it guided my expectations of the researcher on how reality was viewed in the farmer's context (ontological assumptions) and the knowledge acquired (epistemological assumptions).

A consistent classification of positions that are occasionally used equivalently is given by Passey (2020, 2019). According to Passey (2020), all doctoral students are comprehensively obliged to make some creative contribution to knowledge. Choosing a conceptual framework is considered a typical challenge of doctoral research, nevertheless, this is frequently not very well defined at an institutional level. Consequently, some doctorate students are more focused on pure research, which has been termed as pragmatic, while others relate more to policy or practice. Over the years the metaphysical movement of pragmatism started as a result of the essential agreement of some scholars over the denial of traditional conventions regarding the nature of reality, knowledge, and inquest. Maxcy (2003) observed that pragmatists completely rejected the belief that social science investigations can access reality exclusively by using a solitary scientific method.

As an academician and researcher, numerous undergraduate studies in irrigated farming and natural science were supervised and helped in inculcating work experience in applied science, such as participatory projects concerning water resources development. In undertaking this PhD programme in the social science discipline, neither constructivism nor positivism paradigms, the two extremes of philosophical views do fit the researcher's perceptions and views on how best the research would be conducted. Thus, when the researcher became conversant with irrigated farming position and rationality, it was considered to start the research with a problem that needs a solution and, therefore, aims to support practical explanations and clarifications that inform future performance (Creswell, 2014). As a researcher, this is the key to engaging in research efforts relevant to the agricultural sector in general and for farmers in particular. Additionally, the research intends to make a positive impact in accentuating the proper utilisation of water in irrigated farming as climate changes are posing great pressure on limited water resources. Considering the practical value of research particularly in agriculture, a study should be with a participatory approach emphasis and a stratagem of how the findings and results would be disseminated for an impact to happen. Pragmatism as a problem-solving philosophical idea has a corresponding purpose with farmer learning in its goal of contributing to food insecurity and destitution (Vitsitsi, 2019; Farjoun et al., 2015).

The overall objective of this research study was to assess the influence of farmers' learning on water productivity and profitability in smallholder irrigation schemes in Malawi. A water productivity and water scarcity nexus relate to a direct link between how effectively and efficiently water can be used. When water is in short supply, maximising its productivity becomes relevant to guarantee sustainable water resources utilisation in such sectors as agriculture, essentially in irrigated farming, where water requirement is high. This situation, therefore, necessitates farmers to be knowledgeable and willing to participate in learning how to conserve water resources. It is crucially noted to a great extent that the contribution of irrigated farming systems has a greater influence on their livelihoods, consequently, requiring the assessment of crop productivity, profitability, and the livelihood systems involved.

Learning frameworks are means that stipulate learners' outcomes and/or skills that explain, categorise, and identify practical and sector expectations of understanding, and abilities at collective levels of complexity and difficulty. Based on the foregone statement, the researcher considered that case studies were suitable to be used as a research strategy to interrogate and collect information from participating farmers. Case studies (in this work) provided distinguished abilities to investigate the phenomenon of soil water and nutrient content from different perspectives and focus on the relationships and processes between crop productivity and household profitability. Besides, they are imperative because they offer real-life instances of how farmers conduct themselves when new ideas and knowledge are introduced to them and are also a crucial part of gaining and improving their circumstances whether good or bad (Jha and Sani, 2020).

The chapter explores Case Study One as smallholder farmers who use soil water and nutrient devices, Case Study Two as smallholder farmers who are within SIS where they are coping or imitating those using monitoring devices, and Case Study Three as farmers ignorant or not knowledgeable about the soil water and nutrient monitoring devices presence and rationalises the sampling strategies and the research methods for collecting data and information in each of the case studies. The case studies are frequently used when a "why" or "how" question needs to be reacted to. Moreover, they are valuable when attempting to appreciate a complex situation, there is a dearth or limited study on a topic or when practical solutions to a problem are needed. Incidentally for this research, the case studies are effective ways for farmers to essentially apply their talents and their understanding of learned facts to a real-life situation. The case studies are aimed to provide thorough information that can be verified and turning opinions into facts, however, there are also weaknesses, for example, potential researcher bias and the labour-intensive nature of data collection.

Freshwater Availability

Freshwater availability is one of the greatest issues currently experienced by humanity and it has been one of the debatable topics subsequently attracting a wide range of international experts in different disciplines (Zhang et al., 2018; Karnib, 2017; Edokpayi et al., 2017). The rapid population increase coupled with a steady increase in water supplies for agricultural and industrial development has forced harsh pressure on the accessible freshwater resources considering both the quantity and quality. This situation means that judicious management of this scarce important water resource requires steady, vigilant assessment and control for a country's sustainable economic development as alluded to by Merrey et al. (2015).

The crucial role water can play in realising the Sustainable Development Goals is a thorough synthesis of knowledge and recommendations that can be proven through scientific studies for practical farming, monitoring, and capacity development cannot be overemphasised (FAO, 2018; Lema et al., 2003). According to Rangecroft et al. (2020), some well-recognised international institutions and experts have been mandated to conduct scientific research, education, and training in the hydrological field. To search for and address multifaceted water-related challenges and difficulties, accurate, collaborative, and interdisciplinary investigations at the interface of water resources management and agricultural activities are essential. Consequently, new technology developers in the areas of soil water and nutrient conservation are progressively occupied with resolving challenges that social scientists are meeting and becoming involved in fieldwork with participants.

Kumawat et al. (2020) argued that soil and water are the very basic natural resources for agricultural production systems. They observed that extensive farming practices quicken the soil erosion process. Equally, amplified utilisation of water resources can result in water depletion. Hence, holistic soil and water resources management is essential for sustainable development as well as for environmental protection and other natural ecosystems. Acceptance of better technologies that are scientifically developed and tested, sensible use of natural resources, and applicable farming practices and management are necessary for soil water and nutrient conservation for crop production accordingly soil and water are crucial for the presence and survival of all earthly life (Ford et al., 2016; Lal, 2012).

Water is at the core of several important activities currently and projecting into the future, there are many global challenges, and investigations on hydrological handling are increasingly important in the dynamic world (Cosgrove & Loucks, 2015). Water resources are an issue with both nature and humans at its core evidenced by the intertwined linkage between humankind and hydrological systems.

Water Use Efficiency

Water use efficiency (WUE) is a determinant concept of how well water resources is used to grow a crop to a desired outcome. This concept can be used to assess the efficiency of crops, systems, or water use. Increasing water use efficiency or increasing agricultural water productivity is a decisive response to the prevailing growing water shortage that includes the necessity to leave sufficient water in rivers and lakes to protect ecosystems and to meet the rising demands of industries and population growth (Sharma et al., 2015). Knowing this concept is important because it can help to solve and address water scarcity, enhance water quality, and reduce environmental influence. Besides, WUE is a key component of sustainable development goals.

To determine water use efficiency in smallholder irrigation systems, an analysis is usually made concerning the ratio of the total biomass or crop yield produced measured in kilogram per hectare (kg ha^{-1}) to the total water volume used by that crop (measured in cubic millimetres) providing a value of crop yield per unit of water consumed by the crop. By measuring crop harvested either directly measuring water use through estimating using evapotranspiration data water use efficiency can be determined (Villalobos-Cano et al., 2024). The essence is to find out whether water is being used appropriately and minimally. The higher the use efficiency, the lower the water use. Climate change affects the nature and distribution of freshwater resources as well as water management practices. CC affects the nature and distribution of freshwater resources as well as water management practices. Water scarcity due to CC is leading to varied influences and hazards. These threats are conditioned by and can interact with non-climatic drivers that seriously affect water management protocols. WUE is a vital notion that when correctly applied at field plot level can have a prominent impression on water resources use and quality (Kilemo, 2022).

The Nature of the Study

A research study contains original effort in responding a question or solving a problem. As there are several diverse research methods, this chapter emphasises on the approaches that are useful to solve questions or problems that are directly related to everyday smallholder farmer life in irrigated farming. The nature of the research work differs significantly due to the problems, challenges, and areas or disciplines of study (Haq, 2015). Nature of study describes the sample under study and the methods the researcher used to collect and analyse the assembled data and information. It is an overall guide on how the researcher arrived at the conclusions to frame the research study. Conley and Christopher (2001) claimed that the nature of the study in social studies means that much social research comprises direct interaction with respondents. This research will be conducted in three SIS in Dedza District in the Central Region and Chikwawa District in the Southern Region. Newly introduced soil water and nutrient monitoring tools were investigated on the way water application has either changed or not.

Very frequently, smallholder irrigation system assessment approaches fail to meet the needs of policy-makers, managers, and farmers because irrigation performance evaluations are carried out at different levels (Fanadzo and Ncube 2018). This condition shows a misunderstanding gap between farmers and policy-makers that leads to non-operational evaluation systems. The main cause of this is the lack of proof of identity and scrutiny of the rapport between the project purposes, its objectives and the appraisal activities executed. Thus, recognizing the underlying mechanisms that relate evaluable actions to the objectives is of utmost importance in an assessment process (Bos et al, 2005).

This research study has utilised both primary and secondary sources of data to amass quantitative and qualitative information from respondents in three selected smallholder irrigation schemes. Primary data were gathered and examined based on irrigated farming systems, socioeconomic, institutional and management characteristics and other relevant stakeholders. The researcher personally participated through observations and an evaluation survey administered through semi-structured interviews and checklists. Secondary data collection was done through literature reviews. Several reports of Bwanje Valley Irrigation Scheme were consulted as a basis to gain a perception about the context and objectives of the research. However, a selection of different studies and articles on small irrigation systems was done see Table 1.1.

Sustainable Development Recognition as a Production Goal

Sustainable development is a broad notion first extensively revealed by the Brundtland Report also known as '*Our Common Future'* released by the World Commission on Environment and Development. This report introduced the concept of sustainable development and explained how it could be transformed and achieve the objectives therein (Keeble, 1988). Undoubtedly, adopting a sustainability idea with no due regard to an equally thorough explanation can simply lead to misinterpretation and confusion. There is a very close linkage between sustainable economic development and climate change mainly for developing nations as Koubi (2019) observed. One of the critical issues about climate change apparently in several climate zones is the variability in regular rainfall distribution. Unpredictable and inconsistent rainfall distribution that is being experienced means that there can be both an increase and/or decrease in rainfall quantities that may have a direct or indirect effect on household food security and revenue. Climate change results are increasing rainfall erratic distribution and low rainfall, mainly in areas where food insecurity is very high and significantly affects vulnerable groups (Ali et al., 2017; Sauer & Tchale, 2009; Sauer & Zilberman, 2009).

Irrigated farming's main objective is to avert food insecurity by applying sufficient water to crops to equalise atmospheric water demand with what is extracted from the soil. When water is applied to the soil surface it infiltrates into the soil and reallocates under the potential gradient effect (Liste & White, 2008; Miller & Aarstad, 1974; Ogata & Richards, 1957). Water is noted to be misused on smallholder irrigation schemes whereby too much is applied than required. As a consequence, soil nutrients and applied fertilisers are leached rendering soil less fertile (Keraita & Cofie, 2014; Mateo-Sagasta et al., 2013). Low soil fertility results in low productivity and farmers' profitability, which are the key current issues in Malawi's irrigated agriculture.

As widely acknowledged, climate change and variability are causing unprecedented challenges and problems to the achievement of food security and poverty reduction. Colenbrander et al. (2018) argued that using climate finance to advance climate justice by directing resources to the local level is the most pragmatic exercise. Soil water content assessment for advancing water resources management is currently promoted so that uneducated farmers may be able to understand and appreciate soil water conservation. The field capacity concept provides misleading conduct in the water application. Field capacity ca be described as the amount of water content held in soil after surplus water has drained away and its downward movement rate has substantially diminished, which generally takes place within two to three days after rain or water applied during irrigation event. The water monitoring devices have been designed based on this concept, however. Farmers, in smallholder irrigation schemes, who intend to achieve food security and reduce their poverty levels need to learn and overcome water application abuse and increase water use efficiency. Well informed smallholder farmers and knowledgeable can play an important role in the overall success of an irrigation facility as the can ably use water efficiently.

Research Design and Approach

Research design plays a vital role in certifying the validity and reliability of the research study's outcomes. Validity refers to the degree to which the study instrument measures what it anticipates to measure, whereas reliability concerns to the consistency and stability of the research results (Mohajan, 2020). Research design serves as the outline for a complete research investigation that provides a structure, direction, and coherence to the study. The research design is a central phase of ensuring that a study is conducted in a systematic, rigorous, and ethical manner. Thus, the research design elucidates the overall plan and approaches to gathering data and information by integrating different constituents of the study rationally and cogently ensuring the study problem to be studied would successfully be addressed (Asenahabi, 2019).

In a research survey, researchers use questionnaires to collect data and information from the participants responding to the research questions. A questionnaire is a very convenient tool of gathering information from a huge number of people within a set period of time. Therefore, questionnaires that are well-designed are of utmost importance that ensure truthful data is collected so that the findings are interpretable and generalisable. Badly formulated questionnaires make the outcomes uninterpretable, or poorer leading to flawed conclusions.

A questionnaire is initially assessed before it is used to makes sure that it correctly characterises the speculative idea it is anticipated to measure. It is particularly essential when examining concepts that cannot be directly observed or measured, for example happiness or self-confidence. A good questionnaire should, therefore be valid, dependable, flawless, interesting and concise (Taherdoost, 2016). Besides it is designed to allow the assembly of truthful data and information to meet the expected research requirements. It also simplifies data collection, handling, analysis and tabulation ensuring economy on data collection through avoiding collection of any non-essential information. It also permits inclusive and meaningful analysis and purposeful utilization of the data collected.

Essentially, a questionnaire plays a very vital role by interfacing between the researcher and the respondent, and it influences significantly the outcomes of the findings. As a good questionnaire, it ordinarily executes a low burden on respondents and it is alleged as user-friendly by both respondents and interviewers vis-à-vis researchers. According to Sürücü and Maslakci (2020), validity describes the research instrument how it can be used to measure what it should be measured. Validity expounds how well the assembled data includes the actual area of investigation (Ghauri et al., 2020). It essentially means measuring what is intended to be measured.

Cohen et al., (2008) claimed content validity ensures that the components of the key issues to be covered in the research study are both a rational illustration of the broader matter under study and that the components selected for the research sample are resolved in depth and breadth. Besides, content validity explains the extent to which items in the research tool reflect the content world to which the tool will be comprehensive (Straub et al., 2004). It emphasises on the scope to which the research instrument demonstrates proof of correctly and comprehensively analysis of items that it purports to cover. Roebianto et al. (2023) claimed that the items on the research tool need to be tested as to whether the research subject matter can be assessed in accordance with the qualities to be appraised.

Another important strand of validity is “construct validity”. Without construct validity, the research effort can lose precision. It is often considered that construct validity is overarching because it covers all of the other types of issues to be investigated and requires consistent findings across different variables and over time. Thus, construct validity is very vital in research studies because it certifies that a measurement device being used is truthfully seizing the planned abstract concept or construct being assessed, averting the introduction of prejudice and guaranteeing that the findings truly reflect the phenomenon under study (Strauss & Smith, 2009). Construct validity, on the other hand, is relevant. As such construct validity is important because it maintains accurate measurement as it helps ensure that the researcher is measuring the intended construct and not an isolated one (Flake et al. 2022; Mohajan 2017).

To ensure construct validity, the test must be based on acknowledged indicators of introversion or operationalisation. Conversely, content validity measures how well the test characterises all pieces of the construct. The test has little content validity if some characteristics are mislaid or unconnected parts are included. To determine and measure content and construct validity, most frequently content validity depends on people’s knowledge who are conversant with the construct being measured (Newell et al., 2021). Table 3.3 provides some indicators and scores for content and construct validity that helped to assess the research tool used for this research study.

Table 3.3

Indicators for Content and Construct Validity

No	Category of validity	Indicator	Score 1	2	3	4
1	Content validity	a) The information relates to furrow irrigation water application.				√
		b) The information relates to basic skills of smallholder farmers in irrigation schemes.				√
		c) The content of material and topics are applicable to SIS.				√
		d) The monitoring tool is appropriate gadget for the farmer.				√
		e) The information is correct with the farmers' target skills.				√
2	Construct validity	a) The instrument informs the farmer when and how much to irrigate through colour displays.				√
		b) The technology instructions are very easy for farmers to understand.				√
		c) The colour displays are in accord with soil water characteristics to be sensed and measured.				√
		d) Time for the research is reasonably appropriate.			√	
		e) The research tool has covered most aspects and indicators of the water application.				√

Moreover, construct validity concerns the scope to which a test or measure accurately assesses what it is alleged to measure. In research studies, it is imperative to operationalise constructs into existing and measurable attributes that are based on the researcher's knowledge of the construct and its dimensions.

Face validity was also taken into consideration as it is an individual's decision on the construct operationalisation. It is a measure of how relevant an approach, test or method appears to the people who are taking or participating in the investigation. It is a relevant factor because it can affect the perceived credibility of an investigation, and how likely people are to participate in it. It shows the extent to which a measure emerges to be related to a specific construct in the findings of farmers, in this case, the irrigation systems and representatives of smallholder farmers not participating in the use of the new technology. That is, an operation has face validity if its content modestly seems relevant to the individual using the technology. It assesses the questionnaire characteristics concerning practicality, readability, technique reliability and the language's clarity. However, face validity was considered useful to be undertaken since it determines the extent to which a question is personally alleged as covering the idea it purports to measure. It indicates the position of a test as it appears to test the respondents' views. Oluwatayo (2012) claimed that face validity is the researchers' personal views of the presentation and importance of the research measuring tool whether the items appear to be appropriate, rational, explicit and perfect. Therefore, the researcher used content, construct validity and face validity to gain the validity of the research tool.

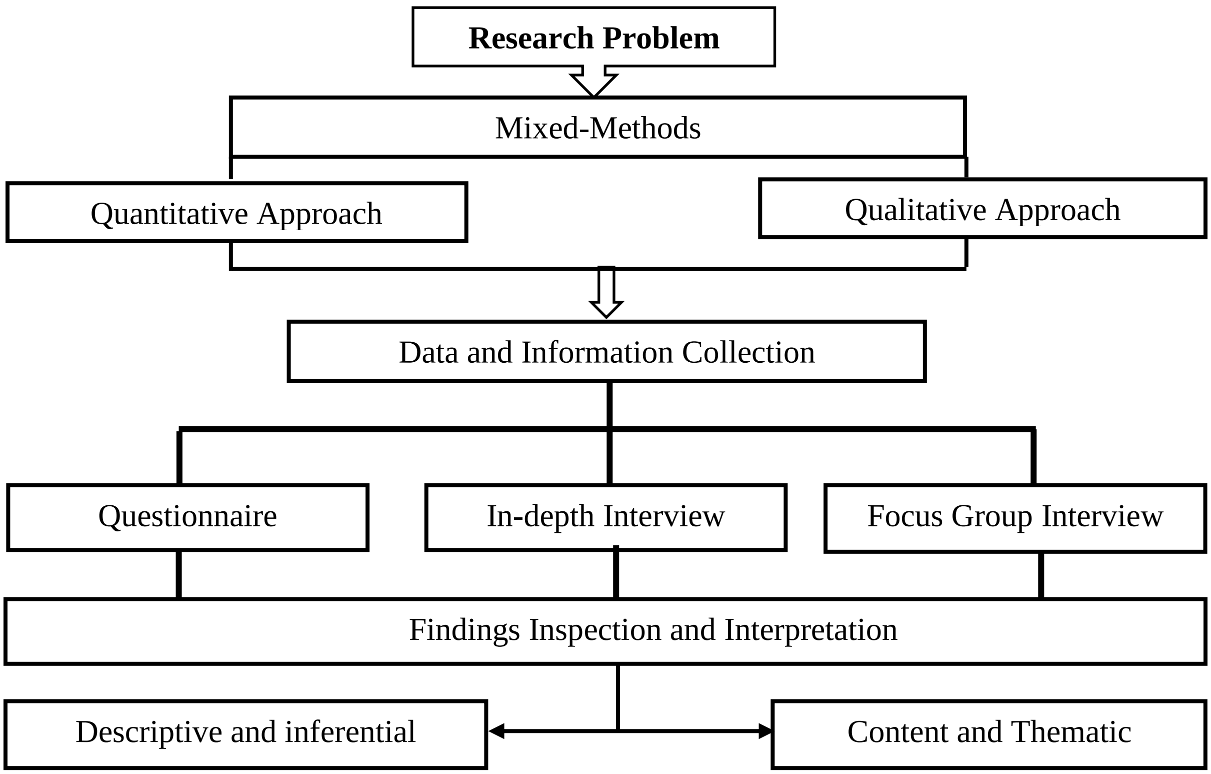
The research design is, largely, a plan through which a researcher chooses to incorporate the various elements of the research study in a comprehensible and consistent manner, in so doing, the researcher focuses on the research study problem as formulated. In other words, it establishes the blueprint for the assembly, dimension, and examination of data and information (Saunders et al., 2012). A research design is envisioned to provide an applicable structure for an investigation. The process may include when, from whom, and under what circumstances, data and information will be obtained to determine the plan used to produce the empirical evidence that will be used to address the research problem (Creswell, 2014; Sileyew, 2019). Building on the research findings, the researcher argues that farmer learning plays an essential role in supporting farmers' capacity to adapt to climate change and weather variability.

The researcher's experience has helped to reveal that an alternate to qualitative minimum effort is to reflect whether qualitative procedures can help understand individual farmers' experiences and the meanings they attach to them without trying to fix them into earlier defined constructs as also claimed by Hammarberg et al. (2016). By letting farmers to explain their reality, researchers learn people's experiences and express their challenges differently about how a technology is being adapted. A mixed-methods approach was used to gather data in the three SIS in Malawi.

Considering the long-lasting challenges of water scarcity, there is a need for wide-ranging assessments that consent understanding the prevailing and likely future development from a holistic perspective, while at the same time fostering learning among smallholder farmers and multiple actors involved to encourage necessary actions (Wiek & Larson, 2012). So, to assess the water resources conditions, systemic, interdisciplinary, and integrative approaches are therefore needed. Figure 3.10 displays how the researcher combined information from diverse sources relating to the same farmer making a richer and more comprehensive dataset that can provide deeper perceptions allowing a holistic view across several collection methods, frequently decreasing the need for wide new data assembly efforts.

Figure 3.10

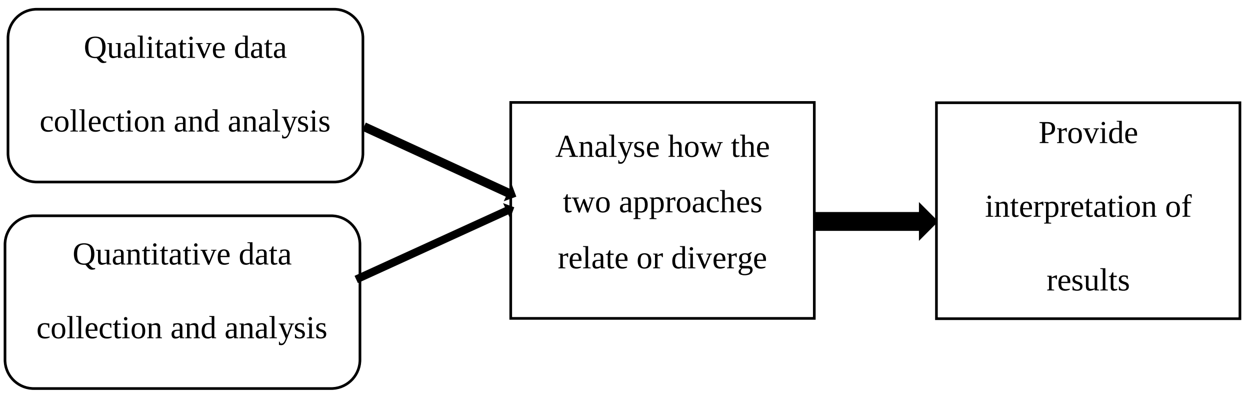
Linkages of Data Collection Process



Mixing qualitative and quantitative approaches has become more common because the mixed-method design offers detailed and thorough data analysis to accomplish the research objectives and accurately respond to the research questions (Bryman, 2006). According to Tashakkori et al. (2020), four types of mixed-method research designs have been used extensively to unravel challenging issues around the world: a) triangulation, b) embedded, c) explanatory and d) exploratory. Conflicting perceptions across farmer group experiences and interests can influence how they respond to efforts to improve water application demand that may be considered as new ways to carry out services research. More often, researchers are only trained and comfortable with a certain methodology, hence the approaches to problems and the types of questions asked are controlled by training limited to one world view. This work fittingly used a simultaneous explanatory model that embraces both qualitative and quantitative data collection. This was based on the fact that the irrigated agricultural sector is presently experiencing numerous challenges and Figure 3.11 shows the integration of qualitative and quantitative data collection emerging from Figure 3.10.

Figure 3.11

Convergent Simultaneous Process



For this study, the integration of qualitative and quantitative approaches was used concurrently to collect data and information. By using these two approaches together, they also checked each other, therefore, providing equal priority and covers the benefits of both techniques (Taherdoost, 2022; Carmichael and Cunningham, 2017; Johnson and Christensen, 2017). By adopting a radical positivist position, it is possible to also observe farming organisations and other social beings in the same manner as physical objects and natural phenomena in a real worldview. As can be noted above, gathering information and data can be characterised by qualitative and quantitative styles considering the nature of data and information required.

This analysis provides essential perceptions into how the productivity and profitability concepts are defined, how they complement the conservative understanding of learning, and how they are linked to adaptation in the social, cultural, and environmental context of smallholder irrigated farming systems (Amadu et al., 2020; Arbuckle Jr et al., 2015). More prominently, it advances the state of knowledge of how farmers' learning outcomes contribute to "fixing" conservative opinions on the importance of farmer-led adaptation. Thus, the diffusion of new ideas within a social grouping is relevant.

The justification of any decision that can be made in irrigated farming is recognised to be dominated by the diffusion of innovations theory that defines how new ideas, behaviours, knowledge or new technologies diffuse through a population progressively, despite all at the same time (Dearing and Cox, 2018). The decisions made usually assume investors vis-à-vis farmers are homogeneous and are thoroughly and perfectly informed and rational. Diffusion is the process by which an innovation is transmitted through some channels over time among the members of a social system in response to learning about an idea like a new evidence-based approach for extending or improving water use in irrigation schemes. According to Stoneman (2018, p. 86), it is generally opined that new technologies change situations over time.

The key question for this research study was, therefore, formulated as, "What difficulties and challenges may hinder the transfer of modern irrigated farming technologies from the smallholder farmers' perspective? However, three main questions directed how this study was carried out and comprised qualitative, quantitative, and mixed methods. As a penultimate chapter, this section presents the research results about farmer learning in enhancing crop productivity and increasing water use efficiency on three selected SIS in Malawi as stated by the researcher in the research questions. The researcher employed a mixed method approach with farmers who participated in this study gathered through questionnaires and interviews. The questionnaire developed by the researcher and before it was used it was test to check it validity and reliability.

Questionnaire Design

Since the research was intended for farmers in irrigated schemes of the age of 18 years and above, it was considered that this requirement should be stated in the cover letter. This would ensure that only the targeted respondents should take part in the survey and no one under 18 years old. It was also suggested that the labelling for the Likert scale should appear on the top of every new page for easy reference by the researcher. Adjustments and improvements to the questionnaire were therefore made. The researcher used SPSS software to help with the qualitative analytical procedure. Since the analytical processes included open, axial and selective coding, the approach adopted was according to Neuman (2011) that guided the analysis. This part of the research study had three aims. Firstly, a pilot study was conducted to determine how respondents understood the questions as set on the questionnaire. Secondly, to inspect whether the distinctions of the group of items truly reflect a specific construct and identify the internal consistency of the questions. Lastly, a reliability analysis was done.

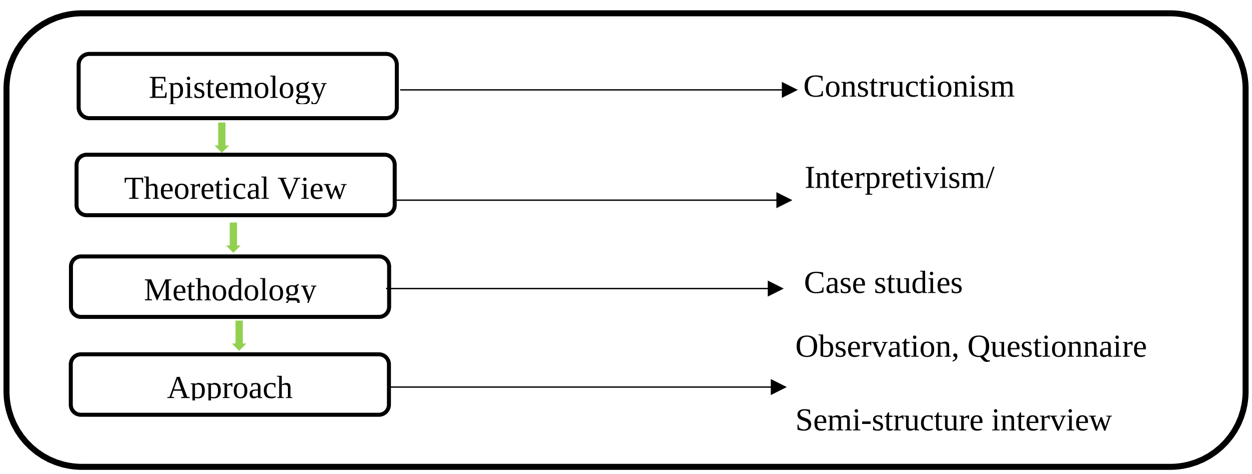
The researcher also examined how the monitoring tools were able to capture the information concerning soil water management skills to enhance household food security and income. This study further explored smallholders' perceptions of the barriers experienced when the monitoring devices were used for learning purposes. Besides, Likert scale questions were used to gauge respondents' attitudes by asking the extent to which they agreed or disagreed with certain questions or statements about water resources Management. As a consequence, through a review of the literature, the researcher built a construct around the Likert scale questions. This approach, essentially, provides a wide-ranging view to the researcher because of using diverse methods as opposed to utilising a particular leading one. Dawadi (2019) used synchronized timing of both quantitative and qualitative approaches to collecting data at the same time, yet independent of one another. He argued that the timing was used to make sure that no opportunity influenced each method as in a sequential design. So, both qualitative and quantitative data in the study were collected concurrently but analysed separately. The findings were combined before interpreting the results.

Philosophical Research Approach

Research philosophy in essence deals with the cause, character and establishment of knowledge. In simple terms, it is the belief about how data about an occurrence or event should be gathered, analysed and used. Although the notion of knowledge creation may appear to be insightful, knowledge creation is pertinent to completing academic studies. Figure 3.12 provides the concepts that have been employed and directed the conduct of this study.

Figure 3.12

Epistemology, theoretical view, methodology, and approach.



Source: Crotty (1998)

Field Survey Procedures

As already explained Bwanje valley, Khamalathu and Mulunga smallholder irrigation schemes in Chikwawa and Dedza Districts were selected to investigate the relevance of the monitoring devices. Since the devices help to inform farmers when and how much to irrigate these schemes were appropriate to be part of the investigation as temporal distribution within the growing period are inmost case below-normal rainfall

A field survey was carried out in three steps. Initially, the researcher visited the area to acquaint himself with the conditions and seek rapport with the scheme management, identify the stakeholders and work out the field logistics. Moreover, the researcher made appointments for meetings with irrigation stakeholders for focus group discussions (FGD). The second step was carried out to meet local traditional leadership and opinion leadership to seek approval to undertake the research in their respective areas.

The researcher took advantage to inform and explain the purpose, objectives and also to emphasise the research process. Introductory letters were delivered and research tools were issued to the leadership to publicise the research *modus operandi* to get a better understanding of what the researcher sought to do and achieve. This step provided an opportunity to select a sample and identify the research respondents. The third step was carrying out field surveys and administration of the questionnaire, FGD and opinion leadership interviews. Responses were verified every day after fieldwork to capture the necessary information and for those responses which did not make sense a follow-up was made for verification. All narratives were reviewed with the scheme management during the mornings. Data analysis ensued a week after fieldwork for the researcher to take advantage of reality before forgetting what happened and not lose the major responses that impinge on the learning of farmers.

One of the most generally echoed essential philosophies concerning learning in the agricultural sector is that farmers are enthusiastic and committed agents which put them at the heart of the training-learning process (Robinson-Pant, 2016). *L*earning is a vital concept in water resources management. It promotes the involvement of farmers themselves to share ideas in various aspects of resource management from planning, water distribution, water use and maintenance of infrastructure. Besides the Theory of Diffusion of Innovations (E. M. Rogers, 2003) casts much light on how the process and the diffusion of innovations (DIT)within a farming sector progresses.

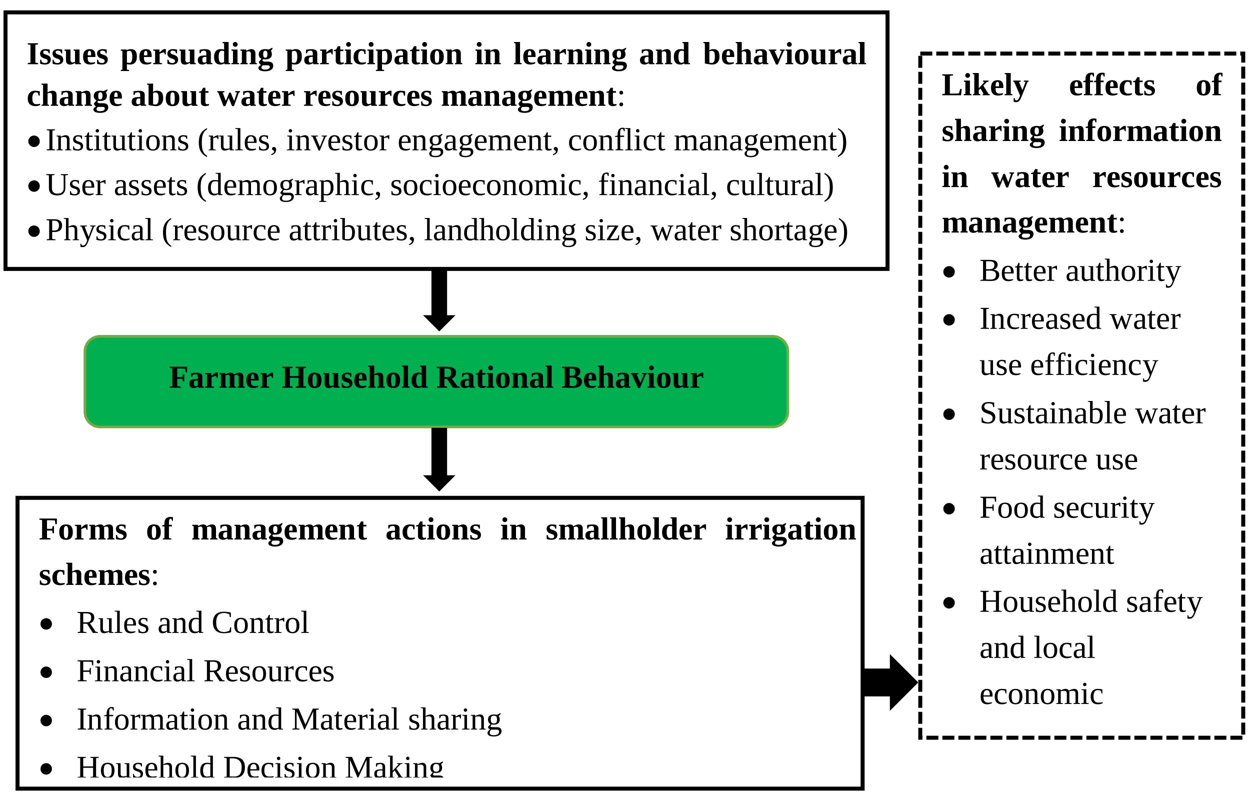
The DIT describes how new concepts, products, or practices spread through people over time, according to a probable pattern where various groups adopt the technology at different stages, with innovators as the first to try it and laggards as the last to adopt (Rambocas and Arjoon 2012; Pannell et al. 2006).). The people may all be influenced by reasons like apparent benefits, compatibility, and awareness. The it explains the process of how a technology introduced is disseminated within a social system over time. Briefly, the theory illustrates diffusion as the process by which technology is publicised through specific channels over time among the fellows of a social system. The features include institutional setting on the irrigation scheme, farmers' socio-cultural-economics, financial circumstances, and physical resource issues. It is noted herein that participation in learning farming activities in SIS differ between and among water users.

Farmer learning as alluded to by DIT it allows for better management of water resources use. Efforts to increase farmer participation in learning new approaches in irrigated farming have been encouraged by the poor performance for instance, water use efficiency, equity and accountability. Increased farmer participation through farmer learning can help to overcome many of the challenges and problems encountered and produce substantial benefits. One water user could participate in more than one activity over the other, and as such a holistic participation measure should be derived.

The engaging farmers in smallholder irrigation farming is key to boosting crop productivity, profitability, ensuring household food security and fostering sustainable development in rural areas globally (Nakawuka, Langan S., et al., 2018). In SSA, where smallscale farming is predominant and water resources are commonly scarce, developing irrigated farming systems is particularly vital (Mabhaudhi et al., 2019). By implementing sustainable farming practices, smallholder farmers worldwide can be instrumental in solving food insecurity, conserving natural resources, curtailing environmental damage, and encouraging long-term agricultural productivity and profitability. Given the critical challenges of water shortage and erratic rainfall in Malawi, smallholder irrigation systems are essential to sustain crop output and adapt to unstable climatic conditions that change personal behaviour. Thus, participation in learning activities like awareness, decision-making, instruction and control, all depend on a farmer's sensible behaviour, as well as the qualities of the water use as displayed in Figure 3.13.

Figure 3.13

Context for Examining Participation in Irrigation Schemes Management



The objective of this type of survey is to evaluate the eventual effects after an intervention has been introduced in the irrigation systems. It is the case of this research, which aims to evaluate the irrigation performance from the perspective of farmers after the soil water monitoring devices have been tried and accepted to be used. Based on these field surveys information concerning perceptions, individual observation and assessments of the irrigated farming systems as well as narratives for possible adoptions of the tools can be heard from those that are part of the assessment of the tools. Through this strategy, the researcher took an opinion poll that aimed to determine in a very simple and quick way farmers' satisfaction towards the tools. As explained above, it measures the degree of satisfaction (level of agreement) through a measuring stick in a scale that goes from -7 to +7. It provides a solid basis to evaluate the performance of the system from farmers' perspective, being adapted to

contexts of high rates of illiteracy for its simplicity. However, in order to obtain unbiased information, several requirements need to be met. Firstly, it is essential to assure the anonymous condition of the informant, given that some farmers might be intimidated or doubtful about the use of the information. Secondly, keep the length of the pool short and specifically a reduced number of personal questions, always placed at the end of the interview. Finally, special effort needs to be done in the translation of the terms 'I fully agree' or 'I fully disagree' that mark both extremes of the stick, since these concepts may not be translatable to every language. This point can be extended to the translation of the whole questionnaire and the definition of each indicator, in order to achieve high quality results.

To determine a suitable sample size to investigate how the issues as noted in the forgone statement is one of the key important issues for a successful research study according to Malterud et al. (2016). For instance, if the sample size is very small, it may not provide effective outcomes or sufficiently characterize the realities of the target population being investigated. Alternatively, whereas larger sample sizes produce smaller margins of error and are more demonstrative, however, a sample size that may be too large may meaningfully increase the cost and time to carry out the investigation. A better and more valuable suggestion for determining research sample sizes is provided by Equation 3.6 (Israel, 2013).

$$\mathbf{n} = \frac{\mathbf{N}}{[\mathbf{1+N(e)^2}]} \qquad \textbf{Equation 3.6}$$

Where "n" is the sample size; "N" is the finite population and "e" is the level of significance or limit of tolerable error and while 1 is a constant. For this research "e" was suggested to be 8.5%.

A few smallholder farmers (20) were given soil water and nutrient monitoring devices per irrigation scheme for deciding when and how much water to apply to their fields. It was assumed that other farmers would emulate what their colleagues were doing. Social learning theory, proposed by Bandura (1969) underscores the significance of perceiving, demonstrating, and emulating the attitudes, behaviours, and emotional reactions of peers. What is important is that social learning theory contemplates how both environmental and cognitive issues interact to influence and encourage human learning to change the prevailing values and behaviour (Akers and Jennings, 2016). Since social vis-à-vis farmer learning is considered to be a conduit of information dissemination to improve water use efficiency and crop productivity, some farmers within the scheme were selected with the help of the scheme managers to participate in this study.

A sampling frame was, therefore, provided by the scheme managers for the other farmers who did not receive the devices from which participants were drawn. Primarily, 18 farmers were considered to participate in each of the selected irrigation schemes of Bwanje Valley, Kasinthula Cane Growers, and Nanzolo Irrigation Schemes. Another 18 farmers from three different smallholder schemes not aware of the soil water and nutrient devices were to be selected summing 162 smallholder farmers. However, 117 respondents accepted to be interrogated. The schemes were Bwanje Valley, Tadala and Tiphunzire in Dedza District, and two irrigation schemes in Chikwawa District, namely Mulunga and Khamalathu. The number seems to be large because much of the information and data collected was assumed large enough to guarantee that many of the observations shall be significant to be detected and identified.

$$\mathbf{n} = \frac{\mathrm{N}}{[1+\mathrm{N}(\mathrm{e})^2]} = \frac{2912}{1+2976(0.075)^2} \frac{2912}{[1+16.38]} = \frac{2912}{17.38} = 167$$

Where: n = sample size for the study (162, see the explanation below); N = total population of household heads in the selected schemes (2912) and e = margin of error (7.5%).

It should be mentioned that 167 was the calculated sample size of the respondents but 162 participants were decided to participate. When the devices were being introduced, 20 farmers were selected to be given the monitoring devices. The researcher decided to involve only18 farmers as a base number, called users, in this study, another 18 participants as imitators of users following what their peers are doing but in the same irrigation scheme and another 18 farmers from another irrigation scheme ignorant of the existence of the monitoring devices. This translates to 54 participants from each irrigation scheme comprising 18 user participants, 18 imitator participants and 18 control participants with a total of 162 participants. This was considered as a balanced sample. The purpose was to get a sample that best replicates the population heterogeneity surveyed by decreasing the estimator variances and limiting costs. The two groups; imitators and control had to have 18 members apiece. A balanced sampling is a random sampling method to make sure that, in the end, once the sample has been determined, the proportions of participants in the samples will be equal for each groups (Hasler and Tillé, 2014).

A total of 117 farmers participated in the research representing 72.2%participation. A total of 45 farmers did not take part due to circumstances beyond their control with nine respondents who failed to participate from Bwanje Valley Smallholder Irrigation Scheme, 22 respondents from Khamalathu Smallholder Irrigation Scheme and 14 respondents from Mulunga Smallholder Irrigation Scheme. Rogelberg and Stanton (2007) claimed that a 100% response rate is scarcely achieved as researchers rely on the alacrity of respondents.

Research Instrument and Data Collection Process

The above sections have tried to corroborate the fact that a tool is particularly necessary but have not defined what data is. Data are the resources for research (Ajayi, 2017). Researchers generate raw data through some procedures of counting, measurement, or observation. The tools and techniques used to assemble data depend mainly on the study's aims and objectives. The data and information the study intends to answer the research questions implied in the set research objectives and help to choose variables to be measured (Tice et al., 2014; Millsap, 2012). Once the variables have been determined to fit the research study, then a study design or an approach to follow when an assembly of the data is selected. The data collection technique is based on the study design where a requisite sample is determined from an interested population. Procedural aspects should include sampling system, delivery method, response rate and method with comparable investigations.

Data collection may practically range from a simple observation of an issue at a location to a complex survey that may cover a widespread area in any part of the globe (Osang et al., 2013). The method chosen and preferred for data collection will largely determine how the data are amassed. The methods commonly employed to assemble the research data comprise questionnaires, observational forms, tape records, or checklists are some strategies used to capture the data (Vartian et al., 2014: Blair et al., 2013). Thus, data collection methods allow researchers to analytically amass data about research objects such as people, animals, crops, phenomena, etc., and about the location and the environment in which these happen to be found.

The requirement for research data collection is to be systematic. This means that the same measuring tool, operational definition of variables, unit of measurement, etc., should be maintained at all points of data assembly. If the data has arbitrarily been collected, it means that challenges and difficulties will be met to answer the research questions decisively (Munyoro, 2018; Fanelli, 2009). However, the rate at which scholars fabricate and forge data is a matter of controversy. Several ways are employed to collect data. The strategy chosen commonly depends on the study objectives, design, and the availability of time, financial resources, and personnel. Thus, a vital concern in deciding the best way to collect the research data is whether the study is intended to produce rather accurate quantitative findings or producing qualitative, descriptive, or narrative information.

Before presenting the issues of the various types of data collection, it is relevant to consider that data collection itself falls under two broad categories, namely: primary and secondary data collection. Primary data collection is the assembly of raw data gathered in the field from the narratives of respondents. It is a procedure of assembling original data for a specific research purpose. Secondary data collection, conversely, refers to the assembly of second-hand data composed by someone who did not generate the data. This is the procedure of amassing data that is already prevailing whether available from published books, journals, periodicals, the internet, etc. It is relatively cheaper and easier to collect than primary data collection. Researchers have the choice between primary and secondary data collection approaches by relying on the nature, scope, and area of research as well as research aims and objectives.

The data collected by researchers may further be categorised into two parts; qualitative research and quantitative collection methods (Kabir, 2016; Butina, 2015). The qualitative methods of data collection essentially do not embrace the collection of data that includes numbers or is determined through a mathematical calculation, rather they are constructed on the non-quantifiable components like feeling, emotion, or passion of the researcher. The exploratory qualitative methods are used by a researcher to inspect a problem that is at the rudimentary stage by answering such questions as what, why, and how (Swedberg, 2020; Ponelis, 2015). Some of the strategies qualitative data collection techniques that can be used may comprise unstructured interviews, focus group discussions, observations, a document study, and content analysis.

Quantitative methods, on the other hand, work with numbers and involve mathematical calculations to deduce evidence. A vivid example from social research would be the use of questionnaires with closed-ended questions that bring out figures for calculation mathematically. Besides, approaches for calculating correlation and regression, mean, mode and median, etc. Most social science research is based on three survey approaches to the quantitative data collection method. They are individual interviews, self-administered questionnaires, and telephone interview methods. These quantitative approaches are vital for attaining information for making forecasts, probabilistic statements, and generalisations. However, most researchers are currently using a blend of qualitative and quantitative data collection methods to acquire the most truthful and representative image of the problem situation (Creswell & Clark, 2017). Using the Mixed-methods approach entails the use of qualitative case studies that comprise real-life investigations that are time-and place-bounded cases according to Yin (2017: 2003). Normally, researchers gather and examine several sources of information, and account for both case descriptions and themes (Creswell & Poth, 2016; Lewis, 2015)

There are some basic research data collection instruments and, for this investigation, those that were used are presented below. They were used individually or as part of extensive methodologies. For instance, some surveys could be organised and applied as a separate tool, but could also be executed as part of an extensive methodology such as a census (Sileyew, 2019). Equally, case studies or stories of transformation can be used separately or individually, but may also be part of a broader procedure.

Interviews

Interviews are perhaps the most common data collection tool used in research studies. They can be conducted with one person at a time (individual interviews) or with groups of people (focus group discussions). The beauty is that they can be administered formally or informally and the answers generated are in most cases of high quality because they are conducted face-to-face. Trust is much more considered (Barrientos et al., 2010; Schmid, 2008). Moreover, interviews may be carried out through already prepared questions and administered via letters or email. Interviews can be structured, semi-structured, or open-ended to elicit answers from respondents (Fox, 2009; Mathers et al., 1998).

Structured interviews are based on a basic package of questions that researchers always ask in the same order to different respondents. Semi-structured interviews may include a basic set of questions, however, it may allow a researcher to ask additional questions or may change the order in which questions were prepared to be asked. Hawkes & Rowe (2008) claimed that most investigations employing semi-structured questionnaires lacked precise wording and phrasing to get information on certain questions. They further argued that probably the lack could be the variances between the respondents being interrogated, or changes in the setting up of the questions posed. Haynes et al. (2008) instead observed that capturing the true intricacy of a threat in a societal milieu with mixed approaches integrating qualitative and quantitative techniques has to be applied. Thus, well-developed approaches of attitude measurement should be applied in awareness investigations. When people are asked to self-assess their level of technology awareness, experience and readiness, nevertheless challenges and/or problems can happen. This is because of the evidences that people may not have the capacity to reckon their authentic knowledge or may not be comfortable to provide an honest response

The researcher, thus conducted face-to-face interviews to assemble and capture information from local leaders, scheme management members, government staff and farmers themselves in the selected schemes. An interview is a short-term secondary social interaction between the researcher and the respondents with the clear aim of gaining information about water resources management. With this approach, questions were elicited in a structured discussion in which the researcher asked pre-formulated questions and the answers were documented. The involvement of scheme management and extension staff was vital which helped to locate the selected households who are involved with irrigation in the schemes. A valid benefit of scheme management staff was that they have vast experience in questionnaire administration as they often work with other researchers in various other studies linked to water utilisation conflicts in the schemes.

Observation

This is the simplest data collection tool as it involves seeing things like activities, objects, relationships, and events that are formally recorded. Different types of observation are conducted in research as either structured or direct observation. This type of observation is a process through which observations are documented against a formal checklist. Whereas, expert observation is generally carried out by a seasoned researcher with exclusive expertise in an area of work (Krueger & Krueger, 2017; Kleinn et al., 2006).

Photography and Video

Photographs and video clips are now part of the research data collection tools that show still or moving images of issues being investigated. Pictures may be used on their own, but are more frequently accompanied by written descriptions that offer extra information. Video clips, on the other hand, are accompanied by an explanation of what they captured. Silver et al. (2019) argued that the use of photography and videos has become progressively important in social research studies over recent years. This is due to developments in smartphone technology that have empowered people to produce inexpensive and high-quality audio-visual products. During the field survey, the researcher captured some images using a digital camera that has been included in the thesis mainly those of crop stand, interviews with respondents and various activities in and around the irrigation schemes. The reasons for capturing incidents were to substantiate some issues that could visibly relay information easily and also to consider the successes and challenges in and around the irrigation scheme. Permission to take images had been obtained before the introductory meetings with the farmers and the scheme management irrigation committee.

Questionnaires and Surveys

A questionnaire is a thoughtful and sensibly designed tool for assembling data based on the terms of the study questions and hypotheses. It prompts narratives from the respondents through a series of questions and/or statements with particular intentions in mind. The questionnaire is administered by the researcher to establish facts, opinions, beliefs, attitudes, and practices that will form the basis of change. Surveys and questionnaires are intended to assemble and record information from several people, groups, or organisations in a steady manner. A questionnaire is a paper form on which research questions have been written. It may be a printed form that researchers and research assistants use to acquire answers and collect data from respondents in the field. The term field is commonly used in survey research to denote the geographical setting where data collection is to be collected from through in-person interviewing and thus the name, field survey (Tracy, 2019; Phillippi & Lauderdale, 2018).

The questionnaire was apportioned into themes to collect specific information and data for each theme. Information collected using the questionnaire included; demographic information, quality of life i.e. (education levels, affluence, land availability and wealth accumulation patterns, just to mention but a few constituents of the Human Development Index), farm employment data, labour hire, agricultural production statistics, etc. As noted earlier, the questionnaire was pre-tested to identify vague statements and errors through a pilot administration. Pilot testing was used due to its several advantages to achieving the research purpose. The researcher, personally, carried out the survey to acquaint with any challenges in understanding how the respondent could respond. One of the benefits of self-administered questionnaires is the capacity to get a better indication of the respondent`s real feelings (Rada & Domínguez-Álvarez, 2014).

The researcher can tell whether the respondent is telling the truth or otherwise. Besides, it allows the researcher to change the questions that might not have been understood by the respondents. Since it is the researcher who intends to understand the issues, s/he controls the scenario and s/he can observe the state in which the respondent was answering the questions. For instance, if the respondent is not well, i.e. drunk, sick, forced or in a sober mind, the answers provided might be changed by these factors. Besides, this also helps in decreasing rejection bias which might falsify the crucial results. Generally, this questionnaire approach is cheaper than other approaches as the researcher can do it alone and can control the pace of the field events (Bryman 2017; Fischer et al., 2014).

Secondary Data and Information

In any scientific research studies published data and information are commonly sought to gather additional data and information that are not readily available. Moreover, they provide relevant reviews of the past statistical history of issues such as rainfall distribution patterns, crop production and hydrological information (Maviza & Ahmed, 2021). This was conducted to make a comparison with the prevailing conditions and also to draw conclusions on the influences of increasing the water use efficiency of the scheme. Baseline surveys to collect demographic data and socio-economic data of census records and Human Development reports were reviewed for the validation of the research findings. Other documents reviewed included state of the environmental reports with permission from the authorities.

Variable Operationalisation

Briefly, to operationalise a variable or an idea in a research setup means the researchers have to explain the variable so that it can be calculated or expressed quantitatively or qualitatively. Selecting which variables to clearly explain in a written assessment is sometimes a judgment call. However, it is generally essential to provide the audience with some ideas of how concepts or variables are chosen and defined they can be defined in several ways (Kivunja and Kuyini, 2017).

The method that a researcher may use to describe and explain the terms can be influenced by his or her area of discipline, training, and prevailing issues instigating the study. Qualitative data comprise characteristics such as markers, labels, and other non-numerical passes. Occasionally they are called categorical data. It may take the form of personal interpretations or documents that demonstrate in detail how people think or respond to various issues they come into contact with within the communities (Friedman, 2012). While data at the ordinal level of measurement may be quantitative or qualitative. They may be arranged in order, ranks, sequences, etc. nevertheless, there are differences between their entries as they are not meaningful. In statistics, it is pertinent to recognise the different data types because analyses can be done only with the help of data kinds. With knowledge of different data types, it helps to use the correct method. Quantitative research, on the other hand, concerns measurement by assigning numerical values to variables that are being studied.

Crop Yield and Water Use as Construct /Variable 1

Smallholder farmers in Malawi exhibit yield gaps in maize (Zea mays, L.) and their outcomes are a multifarious interaction of climatic variations, soil fertility status, socioeconomic issues, and water resources management disparities. Thierfelder et al. (2013) observed that monocropping of maize can be perceived as a contributing factor to soil nutrient depletion and reduced soil fertility levels in Sub-Saharan Africa. Hence, improving soil fertility for smallholder farmers is crucial because it leads to bumper maize yield (Cobo et al., 2010). Improved water resources management, characterised by increasing water use efficiency through user-friendly soil water and nutrient monitoring tools, reduced leaching, and soil protection by cover crops or crop residues, have been proven to increase crop productivity and profitability (Moyo et al., 2020).

Socio-Economic Characteristics Construct /Variable 2

An important factor of the approach to measuring how SIS are impacting households is to evaluate the socio-economic characteristics from the societal level, the community or neighbourhood level, to the individual household level (Kristjanson et al., 2012). If the idea is to examine how new technology is affecting the number of households based on the harvested crop yields, then it is better to identify the number of households that have adequate food supply before and after it takes effect. Ntsonto (2007) alluded to some of the most important examples of socio-economic concerns that include such issues as income levels within a communal setting, economic stability, education access, level of attainment and quality just to mention but a few.

Household Food Security Construct /Variable 3

According to the United Nations' definition of food security, it is that people should have all times, physical, social, and economic access to adequate, safe, and nutritious food that meets their dietary requirements and food preferences for an active and healthy life (Pérez-Escamilla and Segall-Corrêa, 2008). There are, however, five approaches that are commonly used to assess food insecurity. Of these, four are subsidiary or derivative measures of food insecurity. The only process that characterises an important or direct measure of food insecurity is based on household experience (Onori et al., 2021; Smith et al., 2017). Household size is a proxy for food security as it specifies the number of persons a household needs to feed.

House-Dwelling Status Construct /Variable 4

In many rural areas of developing countries, the majority of the population lives in informal settlements, without tenure security and in conditions that are life and health-threatening. For example, 85% of the total population in Malawi resides in rural areas. This statistic suggests the ominous need for good-quality housing. It is observed that there is rapid urbanisation where the youth are going into cities to make ends meet. This has been noted also that it is necessitating more need for housing. To identify the adequacy of housing, the question asking whether a household has a house, the number of rooms whether it is iron-roofed tries to know about the housing conditions. Besides, the affordability of housing is defined by income. Most housing agencies and experts subscribe to the fact that housing may be affordable if it does not cost more than 30% of household income (Cooper and Vohryzek, 2016).

Livestock Ownership Construct/Variable 5

Enhancing and improving rural households' nutritional status is closely linked to women's empowerment. In this study, some questions were formulated that were aimed at reviewing experiences that would identify elements of livestock development from irrigated farming proceeds (De Bruyn, 2017; Smith et al., 2013). Food security is necessarily a woman's job and keeping livestock may help poor women and their families to embark on a process of asset building that will contribute to their empowerment, poverty assuagement, and thereby putting a vital condition for household nutrition improvement. Livestock rearing and production can be done on a wide range of farming systems. According to Sonaiya and Swan (2004) in Africa, extensive grazing by large and small ruminants along river banks and also foraging in the case of chickens, ducks, and pigs. Most rural households keep chicken as one cheap way of getting ready cash and nutrition. Nonetheless, some farmers also keep small ruminants like goats and sheep.

Control variables and device variables

Several research studies have established that the agricultural technology adoption by smallholder farmers is motivated by numerous factors. Due to CC, farmer are currently demanding modern technologies influenced by natural environmental, economic, social and policy factors. Besides, smallholder farmers' experiences, mental and environmental characteristics all have a bearing on adopting water-conserving irrigation (Yamaguchi, et al., 2019). To regulate other factors that may affect farmers' technology acceptance and adoption behaviour, the researcher considered farmers' individual characteristics, household food security characteristics, external environmental characteristics and scheme characteristics as control variables. The ordinal variables, for instance education level, are not the focus of this study and do not influence the research findings even though they restrain the information the dataset can provide, as such the researcher retains the form of the ordinal variable (Dean et al., 2021).

Research Procedures and Ethical Assurances

As water scarcity is ravaging enormously and affecting the majority of residents in the developing world, farmer learning to overcome low agricultural production has become relevant (Graham et al., 2020; Chakkaravarthy & Balakrishnan, 2019). Consequently, there is a need for an investigation to provide a scientific evidence base with accurate informed decision-making to advance a practice (Zegwaard & Hoskyn, 2015). The methodology choice is a decisive issue as it should be decided by the aim of the research study and the nature of the questions that shall help gather necessary information. Other issues worth considering are, for instance, researcher capacity, financial resources, as well as time factors that more often influence the conduct of the study (Flick, 2015). While quantitative studies are the basis for most crop productivity research, there is currently a paradigm shift towards using multiple approaches to identify the best answers to research questions (Coll & Chapman, 2000). Previously social issues were omitted as they concerned multifaceted social behaviours, group dynamics and unique human circumstances.

A researcher pursuing to appreciate, enhance, and conceive a qualitative research method, always starts by using what s/he already knows and builds or improves upon it. It must be realised that researchers have various patterns of concepts and ways of thinking. For any research that involves people as participants, the literature states that the key responsibility of researchers should be to their participants, not to the objectives. Currently, several research designs continue to support some sort of how the research should be conducted and each research design commonly leads to potential ethical concerns. The common ethical values concerning social science research fall into two distinct groups. Firstly, involves how researchers relate to one another and their practical standards and sincere value openness are of vital importance. The second group concerns how researchers relate to their worldview, principally the respondents and the fundamental principles include respect and justice. It should be noted that each research design usually leads to potential ethical concerns and the researcher should consider reducing or surmounting them (Fleming & Zegwaard, 2018).

Farmer learning crucially relies on relationships developed within an irrigation scheme and the community organisations therein. These organisations and institutions play a very important role as to regulate how farmers learn and are treated. According to Bilous et al. (2018), the affairs can be seen as broader than just participants instead of that, they can be noted as collaborators in research inquiry. Using thoughtful practice as a research process, Bilous et al. (2018) shared their skills in the co-construction of knowledge in a cross-cultural situation. Notably, the counterparts were from international organisations with different cultures and a wide variety of professionals such ethical issues were relevant.

The main issue in this section is to present some insights into a range of methodologies and methods that were used with some examples. However, in addition to the importance of selecting an appropriate research methodology and methods, it is the importance of ethical considerations when researching that deal with human beings. According to Fleming (2018), some critical ethical dilemmas are usually met if one is an insider researcher. This includes power differential and ongoing relationships with research participants. Besides, further, consideration of the fundamentals of ethical research involving human participants should seriously be taken on board. Farmer learning new technologies involves mostly rural illiterate people, therefore, human research ethics approval must be obtained. The approval was granted before the commencement of data gathering from the Unicaf University in Zambia Research Ethics Committee. The Ethics Committee offers assistance in resolving ethical issues that may arise from the research protocol and may urge sound decision-making that respects respondents' morals, fears, and interests (Resnik, 2015).

The initial thing that needs to happen here is to answer the question: "What is ethical assurance?" According to the Institute of Business Ethics, ethical assurance is defined as the application of ethical principles to business behaviour, which may be irrigated farming, livestock production etc. Business ethics is important both to the conduct of individuals and to the conduct of the irrigated farming business organisation as a whole (Llamas, 2003). It can be applied to any features of any business conduct, right from meeting room strategies and how organisations treat their members and suppliers to sales techniques and accounting practices. Brook et al. (2015) suggested that ethics goes far beyond the permissible necessities and is, therefore, about flexible decisions and behaviour guided by ideals. In this case, ethical assurance determines whether the flexible decisions and behaviour in the organisation are aligned with ethical values and commitments.

Shared sustainability and sustainability journal reports are progressively contemplated to be tactical issues that attend to institutional pressures from several participants (Boiral et al., 2019; Maroun, 2017). Published reports concerning sustainability support to improve farming business image, communication and social license to function via the dissemination of vital information that may influence social undertakings and expectations (Kassem et al., 2017; Junior et al., 2014) However, the excellence and consistency of such information have been extensively disapproved in the literature as claimed by (Cho et al., 2015; Boiral, 2013). Most of the disparagements are linked to the unfair and hopeful quality of the sustainability information, which is frequently used as collective relational tools rather than dependable and consistent sources of information and data about environmental and social performance as alluded to by many experts like Boiral (2016) and Talbot & Boiral (2015) just to mention but a few.

One of the key objectives of sustainability assurance reports is to resolve this credibility and trustworthiness gap through an outward and supposedly autonomous substantiation of the quality of the revealed data and information. These assurance sustainability reports are supposed and/or intended to condense the information irregularity between the reporter and the audience (Diaz-Sarachaga, 2021). The consistency and added value of such confirmation have been questioned in the literature, for instance, Boiral (2013). Nevertheless, most disapprovals raise ethical issues that are associated with ethical problems as argued by (Ashbaugh, 2004). Gunz and McCutcheon (1991) earlier observed conflicts of obligation and interest, particularly concerning the independence of assurance providers.

Possible conflicts of interest are linked to client-provider relationships while reporting companies and managers capture the business information. It should be noted here that certain organisations may not regard ethical assurance as a priority. Nonetheless, opportunities can be created when investors, customers and suppliers are attracted to doing business with the organisations they trust. For instance, well-graded rice can be bought by a cooperative and add value to the cost of the rice at the farm-gate value (Thorpe & Maestre, 2015). What has been said above in practice, there is a need for inculcating ethical principles in research studies meaning that a researcher has to obtain informed consent from potential respondents; reduce the risk of harm; be very confidential and protect their anonymity, avoid using misleading practices; and also, provide respondents the right to withdraw if need be.

In most cases, research studies are conducted for the government to meet defined, sincere and unmet requirements to inform and transform the conduct of government business and serve the public good better. Social research, like this farmer learning, may help to meet a range of household needs, from food insecurity and how it can successfully be tackled to inform policy and decision-makers, to improving government services and ensuring smallholder farmers have a voice in policy-making that affects them. It is evident that there are ethical lapses in research studies all over the world and is a matter of increasing both public and expert concern. Regarding, the public concern there is over abuses of respondents in research and research misconduct is influenced by several factors such as deceptive reporting, insufficient funding etc. (Börner, 2006). Exert papers of breaches of ethical values, like duplicate publication and research misconduct, regularly emerge in high-impact skilled outlets as well as smaller journals that may put the discipline in disrepute.

Researchers sometimes may perform a wide range of misbehaviours that can be labelled misconduct in the scientific realm (Huistra & Paul, 2021). Clearness and reliability in defining delinquency are fundamentals to creating or evaluating an organizational system for processing misbehaviour allegations, and for appreciating the basic causes to determine effective remedies. An administrative mechanism assortment and modes including prevention and investigation to deal correctly with the diversity of inappropriate behaviours may be needed. It is important to recognise misconduct issues that can be corrected through education or meriting full enquiry (Apalia, 2017).

Informed Consent

Denzin & Lincoln (2017) argued that the basis of ethical research is informed consent from research participants or their acquaintances. The concept involves two vital elements, with each requiring careful consideration: informed and consent. Thus, research participants should be fully notified and informed of what will be expected of them, how the information and data will be utilised, the consequences, if any, and how they will be dealt with. They expect to provide explicit, active, signed consent to taking part in the research, including understanding their rights, that is, information access, right to withdraw at any point if not comfortable etc. This informed consent procedure is a form of contract between the researcher and the participants (Manti & Licari, 2018).

Ethical Expectations

The degree of ethical conduct attention considers personal actions and professional conduct during the research activities. These have a bearing on how respondents answer the questions and both have increased and extended consequences on the community's expectations (Haggerty, 2004). Currently, it is impossible to ask respondents for research purposes without ethical approval. Therefore, a researcher needs evidence of ethics approval. There is, luckily, more information to guide studies around ethically acceptable research methods (Schwandt, 1998).

Risk of Harm, Anonymity and Confidentiality

Farmers are social beings as such it is important that their identity is kept confidential or anonymous and the oaths should go beyond protecting their names. This is to avoid using self-identifying accounts and information. Anonymity and confidentiality are important issues in protecting the respondents from potential harm which might be inconspicuous at face value. Respondent secrecy and privacy are two concepts frequently used synonymously yet they are different. Respondent secrecy means that identity should be unknown to the researcher, for instance, when using anonymous surveys, the respondent's identity should be unknown to the researchers (Novak, 2014). Whereas, respondent privacy means that the identity may be known to the researcher but the data is kept confidential for example when interviews are done identities should not be known to the researcher.

Conflict of Interest

Prevailing relationships with research respondents can create a conflict of interest that may affect the transparency of the research findings. Where the conflict of interest is noted and plays around power variance, removing the source may be the solution. For example, a judge may remove him/herself from a case of corruption in which s/he is alleged to be involved. This may be done by a third party to an anonymous judge to ensure the culprit does not know the judge's identity.

Approaches for Research Questions and Hypothesis Evaluation

For the appropriate research approaches and designs that were implemented in this research work, a quick synopsis is presented. Initially, the data assembly was accomplished through two key data collection instruments namely the interview and the questionnaire. The questions in the checklist for focus group discussions, interviews and questionnaires addressed the research questions and provided ways for hypothesis assessment. For the qualitative approach, the data assembled was coded in an anchor ranking system from 1 to 5 for the multiple-choice questions and from 1 to 5 (Likert scale). For focus group discussions and opinion leadership interviews, the questions were open-ended even though some were closed-ended. The responses were categorised in line with pre-set classes and ascribed to exclusive codes. Each section was separated by questions to be answered.

Both qualitative and quantitative data were gathered. Their analytical procedures included triangulation according to the strategies and benefits highlighted earlier. The data processing software used were Excel and SPSS. The statistical tests consisted of frequency tables and cross-tabulations. It should be noted that the methods for analyses were determined by the nature of the data according to the dependent variable (the predicted or explained variable) and the independent variable (predictor or explaining variable). The research questions were assessed individually with their associated research hypotheses. In this way, those questions that were qualitative, quantitative and mixed were evaluated based on the approaches described below.

Qualitative Approach

Since qualitative questions intended to explore how the respondents experienced the utilisation and benefits accrued from the use of the introduced devices and went through their learning and imitation in the same irrigation scheme. The responses were subjective in nature and varied across the schemes in terms of assumptions and experiences. Krauss (2005) claimed that various qualitative scholars work under diverse epistemological beliefs from those of quantitative investigators. For this research three design selections were involved and are briefly explained and the reasons behind them.

The core activity of the investigation is to understand and appreciate smallholder farmers' perception of crop productivity constraints using various approaches including the method proposed by (Abernethy et al., 2001). The approaches that can attain quantitative levels of a farmer's opinions about irrigation system performance and other kinds of water application challenges will, therefore, be used. Thus, opinion poll that will be formed by a net of indicators, shall further explain a Grid of Indicators. This grid contains a number of that indicates how the interviewee perceives the context of the situation as interrogated. For each one they will have to evaluate the performance on a scale from -5, totally disagree to +5 totally agree.

Grounded theory

It is a renowned methodology engaged in many research investigations in which both qualitative and quantitative data creation systems can be used. The key purpose of the grounded theory is intended to determine or construct a theory from data assembled that is analytically acquired and evaluated through comparative analysis (Timmermans & Tavory, 2012). This theory was applied to some questions in the questionnaire for farmers whether they learnt new knowledge away from what they already know. The example is an open-ended question on the factors influencing farmer participation in using simple irrigation monitoring tools.

Ethnography

Ethnography is a qualitative technique for assembling data and information that is frequently used in the social and behavioural sciences. Data and information are collected through interviews and are narrated by respondents which are then used to determine how individuals function and behave in groups, communities and societies. Watson & Till (2010) argued that ethnography is a kind of qualitative approach that involves engaging a researcher in a group, community or society to observe people's behaviours and interactions very closely.

Case studies

Case studies provide chances for individuals to learn from experiences and encourage the practice of theories. They offer in-depth personal experiences of variables to clarify multifaceted situations. Besides, they are cherished and valuable data sources given the range of learning situations and reasons (Thomas, 2017).

Quantitative Approach

Quantitative research measures attitudes, behaviours, opinions and other variables to support or reject a proposition. This is done by gathering numerical data, which is simply computable to ascertain "statistical significance." This technique inspects the affiliation between variables to assess objective hypotheses and through this approach, three designs were used. For this research therefore quantitative data collection included measurement of water delivery using a Parshall flume to determine water delivery at the field plot level as well as crop yield measurement following the FAO crop statistics protocol that recommends at least three random subplots of size 1 × 1 m to be sampled within each field. Two forms of data need statistical analysis; descriptive and inferential. Descriptive statistics permits to draw conclusions from the collected data while inferential statistics focuses on "statistically significant" differences between two or more groups of data. There are other approaches as well which are discussed below.

Correlational:

The correlational method was used to examine the connections between factors, which are evaluated and documented as research variables (Rad & Yarmohammadian, 2006). This method was used to identify trends and patterns in the assembled data. This test was done by pairing the dependent with the independent variables to see the rapport between the variables in question. For example, a link was created between learning and socioeconomic factors.

Case study

Case studies were used essentially to focus on comparisons between those who were using friendly soil water and nutrient monitoring tools, farmers who were imitating those using monitoring devices but within the same schemes and the control group comprised farmers who were ignorant of the presence of monitoring devices. Three smallholder irrigation schemes were chosen to capture a feasible measure that would represent the situation in water resources management. In this context, the researcher studied these different groups in terms of their socioeconomic characteristics like education levels, gender, marital status etc. For experimental research, the focus is to identify the effect of independent variables on some dependent variables like food security, poverty etc. The causal-comparative investigation is an effort that detects a causative connection between a dependent variable and an independent variable (Patten & Galvan, 2019; Umstead & Mayton, 2018). The rapport between these variables is generally a suggested or proposed connection that is not established because the researcher does not have thorough control over the independent variable.

From the above discourse, it can be understood and noted that the most appropriate investigative approach to the topic under study was a case study whose aim was to realise and explain the beneficial effects of farmer learning and the depth of risk if water resources are misused in irrigated farming. Understanding and increasing water use efficiency as a strategy, adopting both qualitative and quantitative approaches provided a thorough appreciation of water resources management in smallholder irrigation schemes in Malawi.

Design steps

It is well acknowledged that the intention of conducting research studies is characteristically the same irrespective of whichever study area of speciality or career it is being carried out. As recognised, there are several types of research, however, the general intention is to clarify the breach or gap between the prevailing and the best situation. The parts in the research design were selected to match the general research requirements of constructing a well-organised procedure of investigation that strived to discover, interpret, and inform the truth and reality (Mohajan, 2020; Alhadeff-Jones, 2013). Thus, four steps were involved in the conduct of this research and are argued below.

Step One

This step involved illustrating the tasks and creating targets to be completed. Essentially, the procedure was to focus on illuminating the nature and boundaries of the research as well as identifying the questions related to its implementation. In the descriptions of concerns or obstacles, research purpose, significance and contextual information played a crucial role. Particularly, the type of information required was indispensable, as to how it will be used in water resources use decision-making (Cantor et al., 2021).

Step Two

This step involved planning the investigation and constructing how the information will be obtained as well as identifying the resources that will support the fieldwork. Sileyew (2019) argued that a research plan usually serves as a basis for research work. In this step, the methods for assembling requisite information were drawn. The experimental or investigation method investigates whether there is a cause-and-effect association between the study variables. It is the researcher who manipulates and controls independent variables to be measured that may influence either one or more dependent variables. This research type is usually used in scientific fields such as psychology, chemistry and physics. Experimental research includes a range of designs like pre-, quasi and true-experimental, and characteristically consists of parameters such as random or non-random allotment, variables alteration, and utilisation of a control group. For this research experimental arrangements were made but a control group of smallholder farmers who did not have any knowledge of the user-friendly devices were used to establish the relevance of water resources management through increased water use efficiency.

Step Three

This step involved assembling data from respondents identified to provide the necessary information and data to solve the problem identified. A survey or fieldwork was conducted that involved focus group discussions, opinion and leadership interviews and the administration of questionnaires in the selected smallholder irrigation schemes. Questionnaires are the key instrument in social science research as they can be used to collect both quantitative and qualitative information (Rahi, 2017). This step mainly involved comprehending individual farmers' experiences and reflecting on their assumptions or prejudices.

Stage four

The last step in the design process involved assessing the data and information that was collected in step three. The data and information obtained were processed, analysed, and conclusions were made at this step. The research objectives were evaluated and interpreted to solve the research problem using a case study design. The research findings are then presented as a thesis or dissertation herein and understandably so that they may be used to close the gap identified.

Data Collection and Analysis

To gather requisite information for a study the key question one may ask in irrigated farming is, “What difficulties and challenges can hinder the transfer of modern and appropriate irrigated farming technologies from the individual farmer’s perspective? To respond to this question, the data assembly was accomplished through three key data collection instruments namely questionnaire, opinion leader interviews and FGD. A questionnaire comprises of a consistent suite of questions, an interview is a more flexible approach to gather information, while a FGD is a qualitative approach involving a group of individuals discussing a topic of interest. The questions in the checklist for FGD, interviews and questionnaire addressed the research issues and provided ways for hypothesis assessment.

The questions were open-ended even though some were closed-ended to balance for thorough insights to reckon and relate responses. The responses were categorised in line with pre-set classes and ascribed to exclusive codes. Each section was separated by questions to be answered. Both qualitative and quantitative data were gathered. Their analytical procedures included triangulation according to the strategies and benefits highlighted earlier. The data processing software used were Excel and SPSS. The statistical tests consisted of frequency tables and cross-tabulations. It should be noted that the methods for analyses were determined by the nature of the data according to the dependent variable (the predicted or explained variable) and the independent variable (predictor or explaining variable). The research questions were assessed individually with their associated research hypotheses.

Multiple linear regression (MLR), also known as multiple regression, a statistical procedure, employs many explanatory variables to estimate the result of a response variable (Uyanık and Güler, 2013). Its goal is to model a linear correlation between the independent or explanatory variables and dependent or response variables. Based on this, multiple regression extends the principles of ordinary least-squares (OLS) regression as it consists of more than one explanatory variable. So, for the qualitative part of this research Table 3.4 below displays the description of variables used in the regression equations. Through creation of linear correlations based on the amassed data, the multiple linear regression expected to model the link between two or more independent variables and a dependent variable (El Aissaoui, et al., 2019).

Table 3.4

Description of Variables Used in Regression Equations

Dependent variable	Description
Food security	Respondent's capacity available to adapt to environmental conditions (continuous)
Profitability	Respondent's improvement or drop of household revenue
Independent variables	Description
Hands-on learning experience	Farmer's social interactions in knowledge acquisition (continuous)
Partaking learning experience	Farmer's self-learning practices (continuous)
Gender	Dummy variable = 1 if the respondent is female and 0 otherwise
Education	Household head's educational level (categorical coded 1 = illiterate, 2 = primary school (base), 3 = secondary school, 4 = Tertiary and above
Age	Age of respondents (Categorized into seven age groups, coded 1 = 20-29, 2 = 30-39, 3 = 40-49, 4 = 50-59, 5 = 60-69, 6 = 70-79, 7 = >80
Household	Farmer's socio-economic characteristics (Categorical coded 1 = poor (base), 2 = average, 3 = affluent)
Interaction terms	Examining the effects of farmer learning concerning water use efficiency and food security across surveyed selected irrigation schemes.

The procedure facilitates experts to define the deviation of the model and the comparative influence of each independent variable in the overall variance. Schneider et al., (2010) claimed that in many research situations, the intention of statistical investigation is to explain the connections between multiple variables. In a regression equation, the principal variables are the dependent variable (y) that explains the outcome to be predicted, and the independent variables (x), the factors used to forecast the dependent variable. A regression analysis was employed to study the relationships between variables to make predictions, and understand the control effects. Regression is therefore, only referred to the propensity of extreme data values to degenerate to the general mean value (P. Ali & Younas, 2021). The equation characteristically contains a constant term frequently represented by "b0" that foretells the y-intercept, and a regression coefficient "b1". This intercept indicates how much the dependent variable changes when a unit increase in the independent variable is made. Regression analysis is a robust and valuable statistical method with many consequences for water resources management research as it allows researchers to define, forecast and estimate the rapports and draw credible decisions about the unified variables in any considered phenomena. Thus, Table 3.4 displays both dependent and independent variables considered in this study.

A regression model illustrates the likely link between variables that define the applicable intention for the research process and facilitates drawing rational conclusions. The initial variable considered for use in the equation is the one with the biggest positive or negative correlation with the dependent variable (Schober et. al., 2018). It is also occasionally named the dependent variable because it relies on other variables that are independent of any influences. Thus, the variable that is applied to illuminate or expect the response variable is termed the explanatory variable.

Researchers frequently investigate whether there is some connection between two observed variables and to evaluate the strength of this connection.

In empirical studies, using observation and measurement to gain knowledge about the world, can be applied to assess the types of questions that will be asked during the survey, or what information or data points to assemble and focus on. Besides, it might be used to create hypotheses to be tested, or to expedite the explanation of findings and results. On the qualitative side, it might be used to offer the precise types of accounts at different phases of the study process; to ascertain or discover sets of analysis, or to lead and refine the decisions drawn by the research study. All these effects can occur in a single study. However, three main questions directed the collection of data and information for this study and the questions are provided hereunder. In this way, those questions that were qualitative, quantitative and mixed can be estimated based on the approaches displayed in Table 3.4.

To reduce paperwork, the research data collection adopted an Open Data Kit (ODK) source software that proved to be accurate in managing and using data in resource-constrained environments. It permitted offline data collection with smart mobile devices in remote areas. The submission of the data was suitably done when Internet connectivity was available. The collected data was cleaned and the analysis will be performed using the Statistical Package for the Social Sciences where data is required to be coded and then data is entered. The process is so simple even for large data sets. The process of coding data is described below.

In the software, an empty row is clicked where variables are defined. The variable names were required to be unique and usually contained a maximum of 8 characters. These include numeric, commas, dots, scientific notation, date, dollar, custom currency and string. To choose a variable type, a cell grey box is clicked. Then there is a width that refers to the number of characters to be entered for the variable of interest. In the case where a numeric is to be used, the number of decimal places is displayed. In the case of a string of text that explains in detail what a variable represents, a label is given and a maximum of 255 characters containing spaces and punctuation marks can be entered. For categorical data, values need to be specified representing which category. For instance, when coding gender, it is possible to indicate 1 representing male and 2 representing the female. This can be checked by clicking the toe tag icon. On clicking this toe tag icon, it can change between numeric values and their labels.

During data collection, it may be possible to omit or miss some essential information and data in the variable view may be signalled that data is missing. The research assistant entering the data may therefore assign figures of the missing value by either assigning 9, 99 or 999 as discrete missing values. The software would treat these figures as missing and ignore the values. Regarding quantitative measurement, the software indicates the level of quantity of data source. There are three measure properties namely: scale, ordinal and nominal. Interval and ratio levels of measurement are grouped as scale measures. Once coding data is completed and done, the information and data values can be entered and viewed on the display screen. This data analysis can be followed depending on what is to be achieved.

Data and Information and Analytical Techniques

The instruments to be used for research analysis will comprise descriptive statistics such as frequency, percentages and a logistic regression model. Descriptive statistics will be employed to examine the socioeconomic characteristics of the farmers, factors influencing their participation in learning etc. Conversely, a logistic regression model was used to test the hypotheses set up for the study. Roopa (2000) suggested that logistic regression is a method that permits approximating the likelihood that an event will happen or not through the extrapolation of a dichotomous dependent product from a suite of autonomous variables. Statistically, the Logistic Regression Model employs a linear mixture of independent variables to model the log-odds of an event and is represented as Equation 3.7, thus:

$\mathrm{Logit}[P(Y = 1)] = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k$ and the alternate equation, specify $\pi(x)$, is

$$\pi(x) = \frac{\exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k)}{1 + \exp(\alpha + \beta_1 x_1 + \cdots + \beta_k x_k)}$$ **Equation 3.7**

Where P_i is the probability that the dependent variable $Y_i = 1$; if the factor or issue at hand influences the farmer's participation in learning and 0 if otherwise. β_0 is the constant intercept, β_1 is the coefficient of the circumstances that influence the farmer's participation in SIS under investigation.

Measurement of Variables

For information and data gathering from the field survey, smallholder farmers participating in irrigation were the respondents from whom some socio-economic characteristics of farmers were provided and were classified as independent variables while the utilisation of extension information by the respondents, was the dependent variable. Thus, variables are measured at four levels, namely: nominal, ordinal, interval, or ratio. These levels determine how the collected data is examined and eventually statistically analysed, According to (Aini et al., 2018) scale is typically used to inspect and ascertain the value of a qualitative factor in quantitative measurements. Scale is an approach gathered and used to alter a qualitative variable response to quantitative data (Mamabolo & Myers, 2019). In the research world, quantitative and qualitative measurements complement each other that offer unique perceptions into the phenomena being investigated. Whereas quantitative approaches provide numerical data that can be statistically evaluated to detect patterns and trends, qualitative procedures offer rich, comprehensive narratives that discover the depth of personal experiences.

Dependent Variables

The interplay between household food security and well-being among smallholder farmers in the context of increased water use efficiency can influence rapid agrarian change in Malawi. To estimate determinants of smallholder farmers' food insecurity status, the ordered probit model was considered to be appropriate. It demonstrates ordered categorical dependent variables and defines factors that influence smallholder farmers' food security conditions. Food security was the key dependent variable. Household food security status was grouped into five ordered classifications and was framed such that a household could fall into any one of them based on the socioeconomic circumstances of the respondents. The classifications were FS_1 (food-secure), FS_2 (comfortable partial food secure not really food insecure), FS_3 (mildly food-insecure) FS_4 (moderately food-insecure), and FS5 (severely food-insecure). The corresponding classification for food security is undetected and is designated by the latent variable $\mathbf{FS_i}$*. The latent model represents how $\mathbf{FS_i}$* varies considering household characteristics.

$$FS_I^* = XI$$ **Equation 3.8**

Where $\mathbf{FS_i}$* measures the change in the value resulting by individuals from either food-secure, comfortable partial food secure not really food insecure, mildly food-secure, moderately food-insecure, or severely food-insecure. $i = 1, 2, 3 \ldots n$; and n represents the number of respondents. Each individual *i* belongs to one of the four groups whereas *X* is a vector of exogenous variables. The model was used to define smallholder farmers' characteristics predicting food security status at household levels. Models that help explain household food security are as they facilitate understanding how households may access food and measure food insecurity situations. The acquired information can therefore be used to develop policies and programmes that support to enhance household food security (Jones et al., 2013). It is recognised in this research that food insecurity is the foremost challenge in Malawi especially for smallholder farmers who rely very largely on rainfed agriculture for their livelihoods. Key explanatory variable descriptions used, explaining the association between other variables and the expected signs of the prospective outcomes for food security are illustrated in Table 3.5.

Table 3.5

Explanation of Independent Variables Used in the Probit Model

Variables	Measures (Estimate)	Sign
Age	Years	-
Gender	Male = 1; Female = 0	+/-
Marital status	Married = 1; Single = 0	-
Wards or dependants	Number	-
Level of education	Formal education = 1; non-formal education = 0	+
Landholding size	Hectares	+
Land lease	Yes = 1; No = 0	+
Household food availability	Yes = 1; No = 0	+/-
Technology awareness	Yes = 1; No = 0	+
Extension agent visits	Yes = 1; No = 0	+
Social interaction	Yes = 1; No = 0	+
Household monthly revenue	Malawi Kwacha (MK)	+
Household monthly outflow	Malawi Kwacha (MK)	-

Source: Research Survey 2021.

The sign + means the variable is expected to have a positive effect on the dependent variable; - means the variable is expected to have a negative effect on the dependent variable, while +/- means the variable can either influence or negatively influence the dependent variable.

The household head gender is a dummy variable taking a value of 1 if the respondent is male and 0 otherwise. Usually, females are highly dependent and are expected to have fewer opportunities to participate in activities that are income-generating (Alemu et al., 2022).

The household head's marital status is a dummy variable taking 1 if the household head is married and 0 otherwise. Married household heads may have bigger responsibilities due to the number of dependents and they are required to feed more people. A negative effect is expected in the study (Chilemba and Ragasa, 2018)

The number of household wards is an incessant variable whereby a positive effect is likely if the dependents are few and the household is expected to be food-secure as it feeds fewer people compared to a large household (Ngongi and Urassa, 2014).

Female-headed households may be food insecure because of fewer years of education than male household heads. A negative effect on food insecurity is expected (Kakota et al., 2015)

The household head's education level is a dummy variable taking 1 if the household head acquired formal education and 0 otherwise. A positive effect is expected between the level of education and household food security. Food security may be attained with higher levels of education. Education positively influences the change of behaviour in farming practices and dietary decisions (Salima et al., 2023).

Land rent is a dummy variable that takes the value of 1 if the household head rents the household land and 0 otherwise. A household that rents land is likely to be more food-secure than those rent-out land/plots (Garedow, 2010).

Household technology awareness affects the decision to participate in learning new agricultural methods of farming to improve food security and takes 1 and 0 otherwise (Okori et al., 2022).

Social interaction is a precursor to change in behaviour and household affluence. The household head who interacts freely and with several peers may be food secure and takes a value of 1 and 0 otherwise (Nkomoki et al., 2019). A favourable effect is likely to be found in the study.

Landholding size is a continuous variable and is expected to influence food insecurity. If the household has fewer hectares it may affect it negatively (Matavel et al., 2022).

The sign "+" means the dependent variable is likely to have a positive influence, while the sign "–" means it is likely to have a negative influence on the dependent variable.

In this model, probit analysis was adopted simply because it was capable of measuring how a household consumed food. In Table 3.5 a positive sign showed an association with a higher probability of food adequacy and a negative sign otherwise. The probit examination assumes a cumulative normal probability distribution. Consequently, the decision of a farmer to use the devices as a water resources management to increase water use efficiency is dichotomous, involving two mutually exclusive alternatives that are ascribed values of 1 (yes) and 0 (no) Correspondingly, it is suggested that a farmer's decision depends on numerous factors including demographic, production as well as institutional characteristics.

Independent Variables

As can be noted in Table 3.5, the independent variables are variables that stand alone and are not altered by the other variables that are to be measure. They are also called explanatory variables because they explain an incident or effect. For instance: age is defined and computed as the actual age of the respondent at the date of the interview and given in years; farmers' awareness concerning the technology advanced and will be measured using Yes (1) or No (0) as a dichotomous measure; level of education of the respondents measured based on the total number of years spent in school (s). Extension visits as a very vital activity refer to the frequency of extension staff to the respondents or scheme demonstration plot and were identified and measured and assigned scores yes or no. In recent times access to radio is ubiquitous meaning that a person may access information about agriculture from a radio set. If s/he has access and has a radio a score of 1 is assigned, if not, he is assigned as 0.

Social participation: dichotomous responses were appropriate as Yes or No, however, to identify activities during a demonstration of a new technology four social activities/groups were listed for the respondents, namely; Attendance of farmers' council meetings, general meetings, field days, and agricultural shows. The cooperative group dealing with product marketing was also investigated along with the schemes' water users' association. Each of these was apportioned 1 mark, and the summation was made for each respondent on the number of activities s/he participated in. Signs of household revenue and affluence in the irrigated farming sector should be seen in context. Rao (2019) noted that a guiding code in statistical systems design in countries, regardless of their economic growth level, is that signs must reflect the policy resolves for which they are needed. Since this study deals with related factors, however, the simplest regression model to be used for analysis is the binary variable regression analysis presented as Equation 3.6.

$$\mathbf{Y = \beta_0 + \beta_1 X_i + U_i} \qquad \textbf{Equation 3.9}$$

Where: Y is a dependent variable (household income); X_i is a vector of explanatory variables; β0 the invariable; β_i is obliquity, a vector of estimated coefficient of the explanatory variables; U_i is a disturbance or the margin of error term assumed to fulfil all ordinary least square assumptions. A regression equation can be used to solve quantitative data through pretty much and long formulas using software such as Excel, SPPS, SAS etc. (Gujarati et al. 2012). The second model, a multivariate regression vis-à-vis economic model was used to assess household food consumption. This model was selected because it explores the connection across several elements that define socioeconomic factors related to perceptions of household food sufficiency. Besides, the research intended to compare evidence on self-perceived food adequacy from the household surveyed with standard quantitative indicators, namely frequency of eating per day. The model simply regressed to capture variables as follows, household income is the dependent variable:

$$\text{Income} = \beta_0 + \beta_1 \text{ age} + \beta_2 \text{ gender} + \beta_3 \text{ educ} + \beta_4 \text{ marist} + \beta_5 \text{ hosz} + \beta_6 \text{ landsz} + \beta_7 \text{ slope} + \beta_7 \text{ plotdist} + \beta_9 \text{ fertuse } \beta_{10} \text{ irriguse} + \beta_{12} \text{ extension} + \beta_{13} \text{ credit} + \beta_{14} \text{associ} + U_i. \qquad \textbf{Equation 3.10}$$

Farmer Learning Participation

The similarity of farmer learning and smallholder irrigation characteristics will be compared among survey respondents who answered ‘Yes, I would be interested’ and ‘No, I would still not be interested’ to a survey question about interest in participating in learning to improve water application on their plots. The scheme characteristic variables for each group will be assessed separately using T-tests. The T-tests were used to test the differences in means for all continuous variables. They help to determine the efficient use of water resources as it is necessary to balance crop production and the long-term sustainability of irrigated farming systems. The t statistic is calculated as follows:

$$\mathbf{t} = \frac{(\overline{\mathbf{x}_1} - \overline{\mathbf{x}_2}) - \mathbf{m}}{\sqrt{\frac{s_1^2}{n_1} - \frac{s_2^2}{n_2}}} \qquad \textbf{Equation 3.11}$$

Where df = lowest of n_1 -1; n_2 -1 and where s^2p is the pooled variance from the two groups:

$$\mathbf{s_p^2} = \frac{(n_1 - 1)s_2^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \qquad \textbf{Equation 3.12}$$

And m is a constant to which the differences in means are compared. To test whether the variances are unequal, the *F* statistic can be used where:

$F' = [\max (s_1^2, s_2^2) / \min (s_1^2, s_2^2)]$ **Equation 3.13**

If variances are unequal, then the *t* statistic becomes:

$$\mathbf{t} = \frac{\bar{\mathbf{x}}_1 - \bar{\mathbf{x}}_2}{\sqrt{\mathbf{w}_1 - \mathbf{w}_2}}$$ **Equation 3.14**

Where $w_1 = \left[\frac{(S_1^2)}{n_1}\right]$ and $w_2 = \left[\frac{(S_2^2)}{n_2}\right]$ and the Chi-Square test was used to test the difference in frequency of occurrence for all categorical characteristic variables.

Ethical Approval

This research study gained an investigation approval from Unicaf University's Research Ethics Committee and from the Director, Department of Irrigation, Ministry of Agriculture, Malawi. The participants were informed about the objective of the research study before they accepted and signed the written consent form. The researcher assured the participants regarding confidentiality of the information provided. The households were coded by numbers rather than family names to guarantee privacy. Other likely ethical issues were also discussed to eliminate the apprehensions the participants may have held before the interview.

Summary

Malawi over the past two decades has been experiencing erratic rainfall distribution and cries of hunger have been unavoidable since most Malawians depend on the land for survival. However, farming is getting tougher as rainfall is becoming extremely elusive due to climate change and variability (Vitsitsi, 2019). A hectare that once produced 25 bags of 50kg maize can now produce less than five bags. Reports indicate that there is not enough maize to sustain rural households and its price has also gone too high, out of reach of many rural households. While it is undeniable that rain-fed agriculture remains the biggest source of livelihood for Malawians, it is currently observed that its sustainability is under threat from climate change which has shown projections of low crop productivity (C. Hall et al., 2021). Since the country's economy largely depends on agriculture, the dismal performance of the agricultural sub-sectors brings a lot of anxiety to the country’s social and economic welfare. Droughts have been periodic in recent years and very frequent while their severity have, over the years, been increasingly worrisome. Incessant droughts exacerbate poverty while also overloading the country’s fiscal budget which could be used for importing other basics like medical drugs and other essential things (World Bank, 2020; Felton and Siachiwena, 2018). To counterbalance these effects of drought and lessen poverty in communities, there is an urgent need to develop a strong irrigation approach and this cannot be overemphasised as it is the only way Malawi can solve its full agricultural potential and mitigate itself against the undesirable effects of climate change.

CHAPTER 4: FINDINGS

Introduction

This chapter explains the outcomes of the questionnaire relevance for this research study. The questionnaire developed was tested for validity and reliability to authenticate its successful use. A description of the analysis of data assembled has been made and is followed by a discussion of the research findings. The findings are associated with the questions formulated that guided the conduct of the investigation. Then data analysis was conducted to identify, describe and explore the influence of farmer learning on water productivity and profitability in SIS in Malawi and to determine food security and household income in this setting. Essentially, this chapter is divided into three main sections. The first section presents assessment of the questionnaire by examining the reliability and validity of the tool. It then presents the results of descriptive analysis of the respondents interviewed, while the third section presents the econometric analysis that isolates the most significant factors that influence farmers to learn how to increase water use efficiency and household profitability.

Reliability of the Research Tool

An investigation was carried out to produce practical evidence about the validity and reliability of the questionnaire using Rasch Measurement Model Version 3.69.1.11 with Cronbach alpha as a model. The analysis of the research tool assessment revealed that the reliability value found, based on the Cronbach's Alpha (α) value, was 0.97. This explains that the research instruments to be used for the research are exceptional and effective with an extraordinary level of consistency and are relevant for real life research. The researcher also analysed the tool to observe the reliability and isolation of the items and respondents when the value of item reliability is 0.66, while the value of item isolation is 1.50. The value of an individual separation index shows how sound a set of items can discriminate between participants being measured. A higher value shows that the items are more effective at separating the individuals into dissimilar groups. For the Person Separation Index, also called Person Separation Reliability, as with Cronbach α, values above 0.75 imply good reliability, and values above 0.9 specify very good reliability of the scale. A small Item Separation Index demonstrates that the sample is not large enough to detect the items on the latent variable. Table 4.6 displays the statistical summary for reliability and separation index for research items and participant reliability and separation respectively.

Table 4.6

Reliability Statistics and Separation Index Item-Person

Item	**Cronbach's Alpha**	**Item Reliability**	**Item Separation**	**Person Reliability**	**Person Separation**
18	0.96	0.66	1.50	0.97	3.08

According to Bond and Fox (2007) the item reliability value, a value of 0.66 shows to be within acceptable limits. Whereas the item isolation value of 1.50 shows all items are divided into two dimension levels. Linacre (2005) noted that the value for good index isolation is more than the value of 2.0. For the participants' analysis, their reliability value was found to be 0.97. In addition, the isolation index item displayed 3.08, which means a good isolation against the difficulty level according to the items. As such the reliability is very high and very good. Ursachi et al. (2015) elucidated that reliability values above 0.80 are good and are strongly acknowledged.

The isolation value shows four levels of the participants' proficiency to agree on the research items. Thus, a noble isolation importance against the item difficulty level aligns with

Linacre (2005), who elucidated that an isolation value greater than 2.0 is good. The preliminary results found before survey tool administration to respondents show that for the farmer user group who took part in the assessment of the research instrument, the Cronbach alpha estimates were consistently higher than those of control farmer group. One likely explanation maybe that the user group is a similar, and they tend to answer similarly to the items being investigated. From the Table 4.6, the scores were compared with r_{table} of significance where N is 18 items being assessed at the level of significance of 5%. The value on the r_{table} was found to be 0.66. Since the Cronbach alpha values are higher than r table the research tool is reliable.

The verification intended to check the language use to deliver the item issues terms and arrangement of the whole set of questionnaires. In terms of content validation, Reeve and Fayers (2005) acknowledged the ability and relevance of a research tool to measure what should be measured, hence, pre- and post-testing. The pre-test result provides information about both groups' capability in water application. The post-test was also administered to both of groups after the user group applied water according to the colour displayed on the introduced device indicating soil water availability in the rootzone and the control group continued doing what they knew best in water application on their plots, i.e. conventional water application.

The Result of Pre-test

To check the validity, the researcher examined whether the instrument was appropriate to measure what the farmers were supposed to do or not. The result of the test validation is shown in Tables 4.7 and 4.8. In this study, two groups participated in the assessment those using the introduced technology and the control farmer group, those that were ignorant of technology existence. Table 4.7 reveals that the mean scores of pre-tests for the Technology Farmer Group (TFG) was 71.44, whereas the mean of pre-test for Control Farmer Group (CFG) was 79.00.

The biggest score of the users was 84 and the lowest score of experimental class was 60, while the biggest score of control class was 92 and the lowest score was 68. It can be seen that both groups have big difference outcomes. Consequently, it can be established that the technology users' mastery of water application is lower than control group, but there were at the same level of understanding.

Table 4.7

Result of Validation Pre-Test

No	Technology Farmer Group	Control Farmer Group
1	76	72
2	60	76
3	76	80
4	64	84
5	70	92
6	68	72
7	76	68
8	70	88
9	84	84
10	68	76
11	76	88
12	68	72
13	80	78
14	76	88
15	66	84
16	68	68
17	64	80
18	76	72
∑	1286	1422
Mean	71.44	79.00

The Result of Post-test

A post-test is an assessment given to respondents after an instructional programme. Post-tests are frequently used in concurrence with a pre-test to assess the effectiveness of the programme being introduced and the amount of knowledge respondents have gained in the activity. Table 4.8 shows the result of post-test between user and control groups.

Table 4.8

Result of Validation Post-Test

No	Technology Farmer Group	Control Farmer Group
1	76	72
2	80	76
3	84	78
4	80	68
5	84	72
6	72	67
7	76	68
8	90	64
9	84	82
10	72	68
11	80	82
12	68	72
13	80	88
14	76	78
15	72	80
16	70	68
17	83	78
18	76	72
$\sum$	1403	1333
Mean	77.94	74.06

Based on the table above, the mean scores of post-tests for user and control farmer groups are 77.94 and 74.06 respectively. Meanwhile the biggest score for user group was 90 and control class was 88. The lowest score of the user group was 68 and for control class was 64. Consequently, it can be established that the technology mastery of water application in the user group is higher than control group, but were at the same level of understanding during pre-test. The general picture evolving from this study is that the introduced technology can help farmers recognise irrigation concerns for them to develop and improve their understanding of water resources management. This can, therefore, lead to behavioural changes and measurable improvements in irrigation water productivity and household profitability.

Tests Interpretation

Questionnaire, a research instrument, is one of the most extensively used tools to gather data particularly in social science research. The main objective of a questionnaire is to acquire pertinent information in most reliable and valid fashion. Accordingly, the accuracy and consistency of questionnaire forms, important characteristics of research methodology, are known as validity and reliability. Therefore, a questionnaire, as heart of the social investigation, is based on a suite of demands to collect data and information from respondents. The questions are the deciphered form of what a researcher needs to answer for their study which can be addressed through respondents' answers. That are tested before the actual conduct of the research frequently called pilot studies (Kabir, 2016). Yet, the quality and accuracy of data collected vary on how it is planned, utilised, and validated

As it is widely acknowledged that human resources and skill development are important determinants that could positively influence farmers' performance and their disposition to accept and adopt innovations, the researcher decided to verify the significance of the items included in the questionnaire (Abay et al., 2016). To determine the influence of farmer learning on water resources use, the researcher, therefore, employed exploratory factor analysis to decompose the concepts followed by regression analysis. Factor analysis is a method that is conducted to reduce a large number of variables into fewer numbers of factors. This method extracts the maximum common variance from all the variables measured and put them into a joint score (Field, 2009). This analytical technique has been widely used by numerous social researchers in detecting latent factors of farmers' impressions so that they could be available for further analysis (Below et al., 2012; Brown and Raymond, 2007; Jin et al., 2022; Sang et al., 2017).

The principal axis factoring with Varimax rotation was employed to inspect the perception items. Thus, factor loading, as an outcome of analysis, specifies the correlation between an item included in the question and a factor that needs to be assessed, and is a key indicator of a factor's theoretical construct. This process produced three principal factors whose eigenvalue exceeded 1. These results included field (hands-on) learning experience, participatory discussant learning experience and water resources utilisation. Eight items were found to be relevant to the hands-on learning experience as displayed in Table 4.9, accounting for nearly 31% of the common variance with an Eigenvalue of 4.37. Its reliability assessment showed a high Cronbach's alpha ($\alpha = 0.87$). The participatory discussant learning experience included four issues, explaining nearly 15% of the variance and an Eigenvalue of 1.69. Compared to the hands-on learning experience, the latter produced a lower internal consistency level ($\alpha = 0.66$). The water resources use modifiable learning capacity achieved an Eigenvalue of 6.24, with a high level of reliability Cronbach's alpha (α) of 0.83 as can be noted in Table 4.9.

Table 4.9

Factor Loadings for Farmer Learning Items

No	Social learning items	Factor Loading		Uniqueness
		1	2	
	Field (hands-on) Learning Experience			
1	I think the tool is good for soil water monitoring	0.79		0.45
2	Interaction with other farmers based on user-friendly tools is clear and understandable	0.77		0.43
3	Help given by extension staff	0.75		0.49
4	Learning interactions take place during training sessions	0.73		0.39
5	Visits made to farmers using soil water and nutrient devices to learn and follow what they do	0.67		0.59
6	Shared learning and discussions provide compelling initiatives	0.61		0.57
7	Relevance of land and water governance	0.62		0.62
8	Water application discussions during scheme meetings are relevant	0.49		0.74
	Participatory (Demonstration) Discussant Learning Experience			
1	I normally learn from the failures of my fellow farmers and draw lessons from them		0.73	0.51
2	Technology failures provide lessons that are useful for subsequent efforts		0.58	0.61
3	I do strictly follow what I have learned but create my own ways		0.54	0.72
4	Fellow farmers influence my behaviour to learn and use new technology		0.49	0.77
5	I rarely believe things that others do until I experience them myself		0.45	0.72
	Number of items retained	8	5	
	Eigenvalue	4.37	1.69	
	Percentage of explained variance	30.57	14.77	
	Cronbach's alpha (*a*)	0.87	0.66	

Table 4.10

Factor Loadings for Water Resource Use Modifiable Learning Items

No.	Water resource use adaptive capacity	Factor loading	Uniqueness
1	Farmers' learning benefits through irrigated farming are highly known by the government	0.83	0.37
2	The government encourages farmers to learn from each other's water use experiences	0.78	0.43
3	Increasing water use efficiency through learning helps farmers reduce water application and increase productivity	0.73	0.52
4	Farmer earning experiences contribute to improving productivity and profitability	0.69	0.54
5	Shared learning in irrigation schemes helps increase household income	0.68	0.55
6	Sharing information and skills are effective approaches to water resources management	0.63	0.61
7	The government through the Department of Irrigation often organises farmer training on water resources management for farmers to participate in	0.64	0.64
8	The Department of Irrigation provides support to make available relevant technologies	0.57	0.70
9	Water use efficiency technologies offset food insecurity and reduce poverty level	0.65	0.69
10	Sharing irrigated farming experiences with those who not only reside locally but also elsewhere is relevant	0.56	0.71
11	I always receive support from the government during drought and/or flood occurrences	0.54	0.73
12	I presume I have the necessary knowledge and skills to implement modern irrigated farming methods of my own	0.48	0.69
13	Every member of the irrigation schemes has a say in the decision-making process on water resources management	0.46	0.75
	Number of items retained	13	
	Eigenvalue	6.24	
	Cronbach's alpha (*a*)	0.83	

Table 4.11

Factor Loadings for Household Profitability Items

No	Social learning profitability items for farmer learning	Factor Loading 1	2	3	Uniqueness
	Outcomes from Learning Experience				0.32
1	The monitoring device influenced crop yield outcome	0.85			0.38
2	Information shared on water application was appropriate	0.79			0.41
3	Fertiliser improved crop yield as it was within rootzone no leaching	0.70			0.53
4	Frequency of irrigation improved as water applied was based on colour	0.60			0.38
5	Soil quality	0.51			0.32
6	Quality of crops was good		0.76		0.42
7	Selling of produce very crucial		0.82		0.63
8	Distance to market critical		0.55		0.45
9	Road infrastructure		0.43		0.56
10	Price offered for crops		0.53		0.21
11	Generally, soil fertility is good			0.72	0.37
12	Rainfall pattern changing			0.75	0.32
	Number of items retained	5	5	2	
	Eigenvalue	5.86	0.81	0.36	
	Cronbach's alpha (*a*)	0.78	0.69	0.81	

The above three tables display results of a pilot study to check the significance of the formulated research instrument and have shown factor loadings of variable that were examined during the research study. Higher factors loading above 0.7 are more strongly related to the factor. A rule of thumb, factor loadings of 0.3 or higher above are acceptable. In other words, a loading of 0.3, specifies that the factors explain approximately a 30% relationship within the dataset. However, in practical sense, it would show that a third of the variables examined share too much variance, and hence becomes impractical to determine if the variables are correlated with each other or the dependent variable. Thus, factor loading was done to determine whether the research instrument is reliable or not to be used. This tool's reliability was established employing Cronbach's alpha measurement to demonstrate internal consistency. According to Hajjar (2018), a variable is considered reliable when a Cronbach's alpha score is greater than 0.6, tolerable between 0.6 to 0.8, with an adjusted item-total correlation greater than 0.3. From the foregone explanation it can be concluded that the research instrument's outcomes were consistent and therefore usable (Tables 4.9, 4.10 and 4.11).

Appropriately structured, hands-on learning can encourage and inspire smallholder farmers to think outside of the familiar box, persuading them to test and explore their problems with new technologies, and substances they shall work with them on a regular basis. Moreover, it provides opportunities to self-correct any water application mistakes and errors in the moment with an expert guidance at arm's reach. Lived experiences of essential perceptions are recorded in the brain as holistic capabilities, providing the farmers' mind more anchors to tie the memory to (Rudnick et al., 2020). A weighted factor-based measure was used to generate the total scores of the three latent factors (Chen and Li, 2022). Consequently, the item tallies were weighted by their loadings. All picked variables were then multiplied by their equivalent loadings and then summed together. Ultimately, the computation gave final results for the three factors that were treated as continuous variables. However, before completing regression analyses, the mean values of farmer learning and water resources use factors were compared in association with socio-demographic variables using the *t*-test and the one-way analysis of variance techniques.

A set of explanatory variables (age group, gender, education, and household size) were examined respectively. The mean comparisons between the categories in the explanatory variables were examined using the Tukey post hoc test. Multiple ordinary least squares regression equation was used to inspect the connection between farmer learning water resources use. In the equation, farmer learning was the explanatory variable represented by the two latent factors hands-on learning experience and participation in training. Water use efficiency was a response variable represented by its single factor. These equations also comprised other explanatory socio-demographic variables characterised by corresponding dummy variables. The analysis was performed using SPSS v. 20. The equation for the linear regression is shown as Equation 4.15.

$$\mathbf{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon} \qquad \textbf{Equation 4.15}$$

Where Y is a response variable representing water use efficiency. β_0 is the intercept term. β_1, $\beta_2 \ldots$ β_n are the coefficients which correspond to their explanatory variables X_1, $X_2 \ldots$, X_n and ε is an error term. The hands-on learning experience and participation in training (continuous) and the socio-demographic (dummy) variables are the explanatory variable.

Descriptive Statistics

These results are based on cross-sectional data collected from a total of 117 smallholder farmers from the three selected schemes in Malawi (Table 4.12). The descriptive statistics presented include mean, percentage, standard deviation and frequency distribution. In addition, t-test and Chi-Square test statistics were employed to compare technology user group with respect to the hypothesized explanatory variables. Demographic questions were asked to define the general characteristics of the respondents. Table 4.12 presents demographic results from field survey. Demographics help tapping comprehensive evidence on smallholder farmers' characteristics of. Essentially it characterises the sample by providing vital information for comparing research studies (Vasileiou et al., 2018).

Table 4.12

Respondent Demographic Characteristics across Selected Irrigation Schemes

Factor	Frequency (117)	Percentage (%)
Gender		
Male	77	65.8
Female	40	34.2
Age (years)		
20-29	14	12.0
30-39	31	26.5
40-49	30	25.6
50-59	21	17.9
60–69	13	11.1
70-79	7	6.0
80-89	1	0.9
Educational level		
Never attended	46	39.3
Primary school	54	46.2
Secondary school	17	14.5
Marital status		
Married	90	76.9
Married spouse absent	1	1.7
Single	4	3.4
Separated	4	3.4
Widower	17	14.6

Source: Research survey data 2021

Based on this table, the proportion of males and females is not equally distributed. About two-thirds (66%) of the sample population were males. Their age was spread across seven categories. Those within the range of 30-39 years of age accounted for the highest proportion (26.5%), followed by those aged 40–49 years (25.6%), then the age group of 50-59 years (17.9%). The number of respondents aged over 70 years had the lowest proportion (6.9%) contrastingly the number of respondents aged under 30 years was 12%. The mean age was 45.6 years with a standard error of 1.253 years. The median and mode were 43 and 40 years respectively with a minimum age of 22 years and 82 years as the maximum. The situation of the six SIS regarding education for farmers varied considerably. Moreover, Table 4.12 includes a small proportion of the respondents who acquired secondary education (14.5%) compared to those who only attended primary education (46.2%) and non-formal education (39.3%). This finding concerning education for never and only attended primary school, the most common reason is lack of money because of poverty to pay school fees and uniforms. The second reason is being orphaned with no one to help, and lastly, schools are far away from their villages. The findings are consistent with what Al-Samarrai and Zaman, (2007) and Kusakabe, (2018) also found when they conducted studies on education in Malawi.

Concerning marital status, 76.9% were in a ‘living together’ relationship with about 1% in marital union and 21.3% separated, divorced and widowed. With the level of education achieved by respondents, the outcomes show that men who attained secondary and primary school education are 1.8 times and 1.5 times respectively, more likely to favour smaller family sizes than those with primary education.

Education is a factor that is relevant for enhancing agricultural productivity. It provides farmers access to information concerning produce prices, marketing times and places. This sanctions farmers to discuss and negotiate for better prices when buying inputs and selling produce. It has been acknowledged that determinants of agricultural productivity across nations has shown significant positive coefficients for learning vis-à-vis education variables suggesting that higher levels of education lead to higher productivity (Reimers and Klasen, 2013). Hence, learning for improving production can be argued as a vital ingredient to overcoming development challenges in smallholder agricultural sector. Ozturk (2008) claimed that education is recognised to be a leading factor of development. No country can develop if it does not invest considerable financial resources in human capital as education vis-à-vis learning promotes citizens' productivity and creativity and encourages entrepreneurship and technological developments.

It can also be noted in Table 4.12 that 64.1% were younger than 49 years of age, implying that more young people are involved in irrigated farming as their income-generating activity as alluded to by some opinion leadership during the interviews. The youth are pivotal to the social, cultural, economic, and political growth of developed and developing nations if only productive strategies are applied and appraised in line with population development. The engagement of the youth in the agricultural sector may be of greater concern in many emerging economies generally and Malawi particularly (Mungai et al., 2020; Chinsinga and Chasukwa, 2012). This comes about because of the non-creation of jobs or employment by the governments even though a clear number of employees may be required by the governments to function effectively in various capacities.

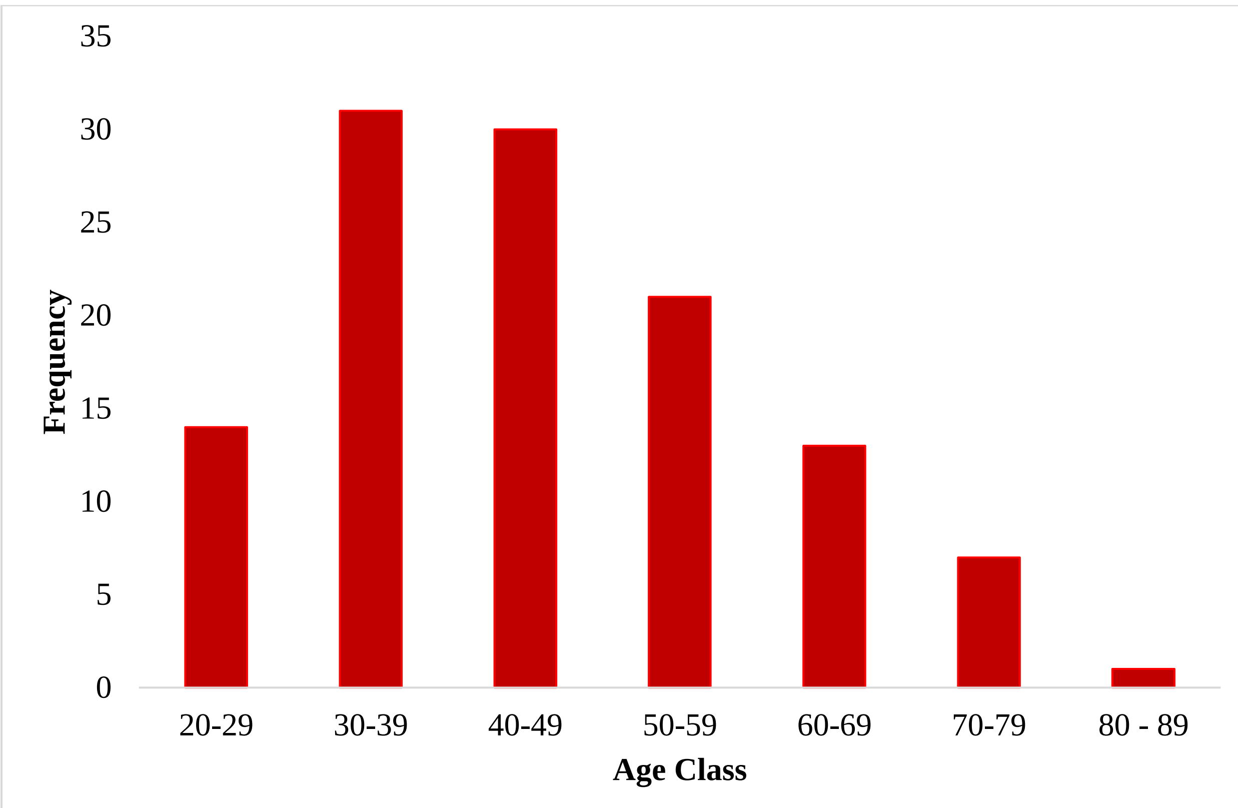
Based on participants' interviews per scheme, the numbers of men who were interviewed were higher than that of women in the selected schemes surveyed. The total number of respondents comprised 117 households where 45 were from Bwanje Valley, 32 households were from Khamalathu and 40 were from Mulunga. All these irrigation schemes had a control irrigation scheme that knew nothing about the soil water and nutrient monitoring devices and how they looked. Contrastingly, the age differences between women and men interviewed were 48.5 and 41.7; 48.8 and 42.2; and 53.3 and 45.5 years for Bwanje Valley, Khamalathu and Mulunga Irrigation Schemes respectively. While women are commonly thought to implement the greater part of work in agriculture, they are excluded from learning new methods of farming practices. This is generally so in Sub-Saharan Africa and Malawi (Maertens et al., 2021).

The frequency distribution of respondents is used in research studies to establish and present data in a manner that makes it simpler to comprehend. It is significant because it helps to appreciate the distribution of data and glean conclusions from it. Its purpose is to look into the effects of learning on the development of water resources management strategies by farmers in small-scale irrigation systems globally and Malawi particularly. From the findings, it can be noted that many of the respondents were between the ages of 30 and 49 years seconded by the 50 to 59 years indicating that more youth are participating in agricultural-related activities in Malawi and one reason could be lack of job creation opportunities by the government. Farmer's age is very important in irrigated farming because young farmers are largely more productive than older farmers. The marginal influence of a farmer's age suggests that a unit increase in age of a farmer by an additional year may increase smallholder irrigation farm participation, thus. improving smallholder farmer's welfare. The household size was used as a proxy for family labour. An average household size is a convenient statistic for assessing a living income and poverty ranks mainly in emerging nations. It can also be used to represent typical family tasks.

Figure 4.14 displays the class age frequency distribution for the respondents across the surveyed smallholder schemes in the two districts of Dedza and Chikwawa. It shows the respondents falling into different age groups, essentially providing an analysis of farmer demographics in the selected smallholder irrigation schemes based on their age. This type of analysis helps to appreciate if their sample represents an assorted age range and to examine likely age-related trends. According to NSO (2019), the age and gender pyramid displays that Malawi's population is youthful but also evolving from high to low fertility status as proven by the contracting base of a population aged between 0 to 4 years. This fertility rate decline is because of a number of factors, for example, an educated populace reduces the window of motherhood and the age at which people marry has also increased.

Figure 4.14

Class Age Frequency of Respondents across the SIS



With more than 76% of the population below the age of 35 years, and accounting for three-quarters of the population, Malawi is a youthful country. However, the youth face numerous and intersected challenges. Faysse et al. (2020) observed that the nonexistence of youth engagement in agriculture activities is of great concern in many developing economies. In these countries and to capricious degrees, the rural youth may choose between engaging in non-agricultural related activities opting to go into urban areas where they think they may get lucrative opportunities rather than engaging in agriculture which they think is dirty (Meena, 2018). Remarkably, households in poverty, those who make their livelihood through agriculture, may have more kids as a way of supporting the household with labour. As established by the research findings, marital status is a function of the demographic and socioeconomic characteristics of the household.

Water use efficiency improvement and crop productivity are major concerns in irrigated farming. Water use efficiency is directly linked to farm productivity and profitability based on soil quality, water conservation, and sustainable use (Spencer et al., 2019; Armstrong, 2004). While it is well acknowledged that water application efficiency is comparatively lower in furrow irrigation systems this is the key reason that farmers should learn how to apply less water using user-friendly tools. Smallholder farmers need to know how much and when to apply water on their farm plots (Stirzaker et al., 2014). Poor farmers can therefore use colour codes displayed on chameleon (a device introduced in selected smallholder schemes) as proxies of soil water content and inform them when and how much to apply water.

Soil water and nutrient tools allow observing what is taking place in the crop’s rootzone concerning water infiltration during and after irrigations, more importantly during water consumption by plants. Having knowledgeable information, water application decisions concerning when and how much water to apply to circumvent crop water stresses is vital. Smallholder farmers' irrigation groups utilise conveyance structures to deliver water to their plots to promote good crop growth and maintain suitable levels of soil water content (Muyanga et al., 2020; Nhamo et al., 2016). Reports have revealed that despite the efforts made, equitable water distribution remains a challenge in SIS in Malawi as conflicts between and among farmers persist. If innovative practices that promote effective water application on farmers’ plots and good governance are adopted can, certainly, influence water's economic and labour advantage while also lessening environmental problems.

Livelihood dependence Characteristics

A question was asked about farmer's livelihood dependence. This question was based on the fact that non-farm activities are sometimes a way of livelihood maintenance and is considered as a justifiable means to balancing the economic, social, cultural, and environmental dimensions of sustainable livelihood. Currently, the weakening influence of the agricultural sector and its incapability to provide decent livelihood has been recognised to be a social challenge in rural areas globally because this sector can no longer offer rural livelihood by itself (Shabanali et al., 2021). However, irrigated farming has been recognised to circumvent this situation. According to Giordano et al., (2019) continued investments in irrigated farming, even though not following past models, must play a key role in relieving food insecurity and joblessness pressure. Table 4.13 shows that 76.9% of farmer households in the selected irrigation schemes regarded irrigated farming as the main source contributing to their livelihood, whereas 12.0% had some income-generating activities but included irrigated farming while 11.1% had other sources of income that also included irrigated farming.

Table 4.13

Farmers' Livelihood Dependence and Other Sources across Schemes

Wage	Frequency	Percent	Cumulative %
Farming Dependence (0)	90	76.9	76.9
Farming with business (1)	14	12.0	88.9
Farming with business and other income-generating activities (2)	13	11.1	100
Total	117	100	

It has been reported that the majority of smallholder farmers are showing interest in irrigated farming because a sizeable proportion indicated that income from irrigated farming improved household welfare and were able to pay school fees for their dependents (Nguluwe, 2022). Adapting to climate threats is the key to increasing food security and improving the resilience of irrigated farming systems. Farmers indicated that they have satisfactory access to livelihood desire, for instance, physical, human and natural capital as well as skill learning, however access to financial capital that comprises credit from banks and government subsidies is not sufficient. Significant factors of livelihood strategies of farmers were marital status ($t = 2.43$), household size ($t = 5.87$), non-farm activity ($t = 1.93$) and income ($t = 6.37$).

The share of farmers using devices, imitators and non-users (control) in terms of gender, extension delivery services, and education levels are presented in Table 4.14. Furthermore, it shows calculated Chi-Square statistics used for examining relationships between these categorical variables. Evidence from the sample shows that there is a significant difference in the manner in which farmers were learning based on extension advice and education and there was equal learning regardless of gender.

The calculated Chi-Square values for extension delivery and education are much larger than the critical value of 14.06 meaning that there is a significant difference in learning efficient ways of water resource use between women and men and their respective null hypotheses are rejected. The gender's null hypothesis of equal learning is sustained because it is less than the critical value of 14.06. A women imitator farmer from Bwanje Valley Irrigation Scheme who did not receive the soil and nutrient monitoring devices narrated that she had been following (imitating) what her neighbour who had the devices was doing. She indicated that her harvests improved significantly as she had been harvesting one basket of 45 kg before against more than three 50 kg bags of beans.

Table 4.14

Soil Water and Nutrient Device Users, Imitators and Control Group Ratios across Categorical Variables on Selected SIS

	Bwanje Valley				Khamalathu				Mulunga				
Characteristics	Users	Imitators	Control	Total	Users	Imitators	Control	Total	Users	Imitators	Control	Total	
Gender													Chi^2
Female	2	4	5	11	4	6	5	15	12	4	2	18	
	(12%)	(27%)	(36%)	(24%)	(31%)	(55%)	(63%)	(47%)	(54%)	(40%)	(25%)	(45%)	12.058
Male	14	11	9	34	9	5	3	17	10	6	6	22	
	(88%)	(73%)	(64%)	(76)	(69%)	(45%)	(37%)	(53%)	(46%)	(60%)	(75%)	(55%)	
Agricultural improvement services (extension delivery)													
Yes	16	9	8	33	13	7	6	26	22	6	5	33	
	(100%)	(60%)	(57%)	(73%)	(100%)	(64%)	(75%)	(81%)	(82%)	(60%)	(62%)	(82%)	34.879
No	(0%)	6	6	14	0	4	2	9	0	4	3	11	
		(40%)	(43%)	(27%)	(0%)	(36%)	(25%)	(19%)	(18%)	(40%)	(38%)	(18%)	
Education													
No school	2	3	4	9	8	4	4	16	11	7	3	21	
	(12%)	(20%)	(28%)	(20%)	(62%)	(36%)	(50%)	(50%)	(50%)	(70%)	(38%)	(52%)	
Primary school	11	8	7	26	5	6	3	14	7	3	4	14	19.696
	(69%)	(53%)	(50%)	(58%)	(38%)	(55%)	(38%)	(44%)	(32%)	(30%)	(50%)	(35%)	
Secondary	3	4	3	10	0	1	1	2	4	0	1	5	
school	(19%)	(27%)	(21%)	(22%)	(%)	(9%)	(12%)	(6%)	(18%)	(%)	(13%)	(13%)	

Source: Field survey data computation, 2021.

Regarding household food security, she observed that she harvests more than adequate to sustain her family of four a thing of the past. The extra maize harvest is sold contributing to her household income. These observations can be attributed to knowledge acquisition concerning the frequency and quantity of water application from observing her neighbour. *Assuring water application frequency* is a crucial step in improving crop productivity. Irrigation scheduling has been a major challenge in almost all irrigation schemes in Malawi (Gwiyani-Nkhoma, 2013; Njoloma et al., 2009). Under-irrigation and/or over-irrigation have frequently led to poor crop productivity aggravated by erratic rainfall distribution that exposes smallholder farmers to incessant shocks of droughts and floods. Although the respondents were identified with farmer learning, and frequently with water use efficiency, they also specified that their irrigation plots are not economically worthwhile.

This subject developed alongside discussions of climate change and extensive irrigated farming sustainability. One respondent narrated that the influence of SIS is essentially a springboard for growing crops for household food security and income during water shortages due to rainfall erraticism. Regarding the profitable possibility side of it, is up for water resources conservation, nevertheless, we are proud now of this opportunity to learn how to apply water at the right time and amount a thing that we have been unable to do.

Landholding on the schemes appeared to be the most vital factor of crop production. Since most of these are semi-government-managed, the land is allocated to them and most farmers are given 0.4 hectares. From the FGDs and opinion leadership consultations, customary, gift, rented, leased and shared cropping lands are common farming practices. Shared cropping and rented lands are generally conducted on a contractual basis in these irrigation schemes. This happens when an individual fails to cultivate his/her land due to some circumstances beyond control. The contract may be for a short time. Distance from homesteads to the irrigation schemes was given as one of the reasons some farmers were renting out their plots as distance varied between 0.5 km for those close to the scheme and 3.5 km for those residing far away from the scheme

Crop Productivity for Female-Headed Households

A question was formulated asking, "Is there any association between farmer learning and gender? The researcher devised a hypothesis that there is no significant link between farmer learning and gender. Table 4.9 displays the proportion of learners (device users and imitator farmers) and gender (women and men). There is a significant difference in farmer learning new methods of water application between women and men. It was noted on average that more men participated in learning new skills about water applications using user-friendly tools. Despite the role women play in solving food insecurity, they are often omitted from crop production trainings and other initiatives on natural resources management as evidenced in this study.

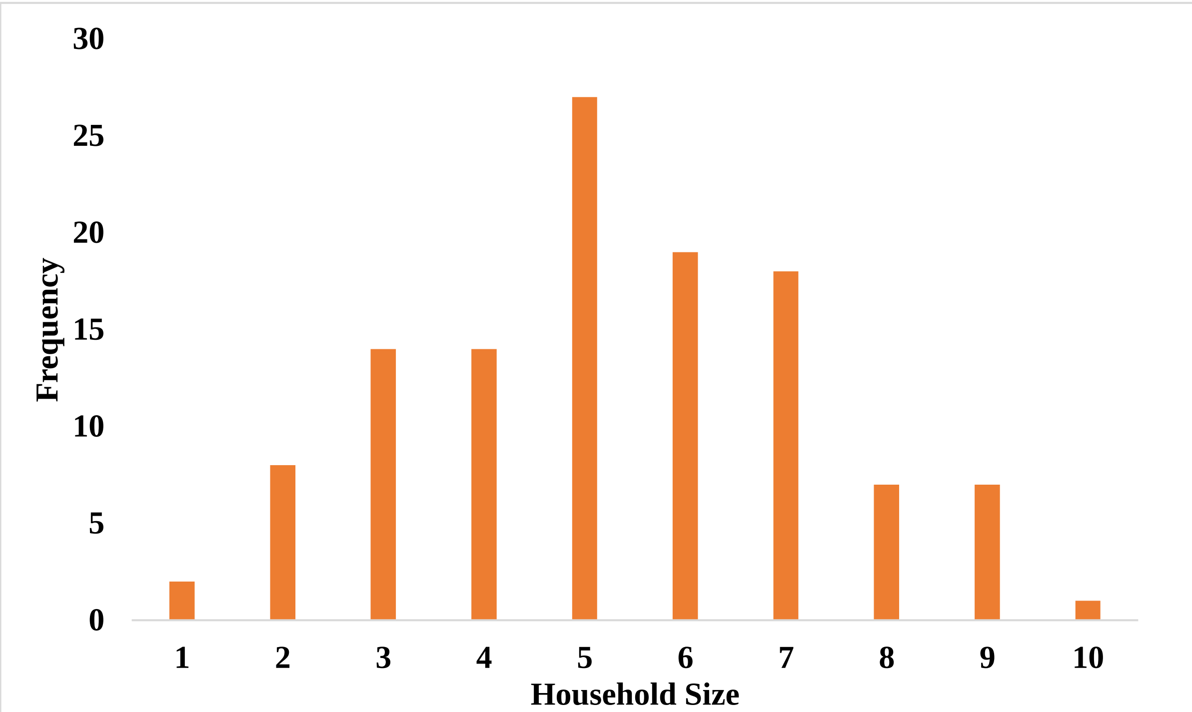
Women's inadequate access to agricultural technology training is an important constraint to overall crop productivity, then there is, therefore, a need for them to be considered equal partners with men. From the findings of this research, the null hypothesis of equal access to agricultural training is rejected in favour of the alternative hypothesis. From the findings of this research, the null hypothesis of equal access to agricultural training is rejected in favour of the alternative hypothesis. This finding is similar to the works of other experts in agriculture (Croppenstedt et al., 2013; Huyer, 2016; Obayelu et al., 2020).

As smallholder farmers through their labour on family gardens, farms, and other agricultural enterprises, women influence agriculture in developing countries. Moreover, there is ample evidence of gender differences in agricultural productivity. For example, comparisons can be made on crop yields for male- and female-headed households. Evidence from several studies points to lower yields on farms run by women. Tiruneh et al. (2001) noted that female-headed households' output was 35 percent lower value per hectare than their peers. Similarly, Horrell and Krishnan (2007) observed lower yields for widowed or de facto female-headed households and were significantly poorer on a monetary income measure than their male-headed counterparts (p. 1378).

Food Security and Household Characteristics

Environmental shocks commonly pressurise food security in countries that rely very heavily on rain-fed agriculture (Ludi, 2009). Food insecurity at the household level is associated with numerous factors, including household head gender, age, income, education, occupation, food price and household size. Figure 4.15 shows the household structure of the selected irrigation schemes in the two districts.

Figure 4.15



Household Structure in the SIS

The findings revealed that most families were composed of five persons. In 2019, the average household size in Sub-Saharan Africa was nearly 7 members per household, which was the biggest average household size globally. Comparing with Europe, only 3 members comprise a household.

Household size explains the number of people found in a household, while household structure discusses the composition of people. So, household description plays a decisive role in smallholder farmer's lives. The household structure and the manner they change over time are the pivotal points of wide changes in society, consisting demographic dynamics, changes in standards, and economic transformations that have effects in areas like poverty, labour provisions or gender dynamics. The key characteristic of the analysis was to ascertain the factors that may explain food insecurity and the poverty status of the households and to determine how these factors influence the risk of household food security and poverty. Table 4.15 shows logistic regression for the household structure.

Table 4.15

Logistic Regression for Household Structure

	B	S.E.	Wald	Sig.	Exp (B)	95.% Lower	95.% Upper
Children	0.371	0.097	14.032	0.000	1.538	1.199	1.768
Older people	0.197	0.121	2.561	0.111	1.241	0.979	1.586
Both age group	0.141	0.179	0.593	0.437	1.167	0.809	1.602
Household size	-0.083	0.019	19.734	0.000	0.793	0.879	0.975
Constant	0.638	0.109	31.372	0.000	1.798		

The researcher examined the relationship between the dichotomous dependent variable household size and several independent variables to clarify the likelihood of a household being food insecure and poor. Regression exploration is generally conducted to detect the influences of several attributes that contribute to household expenditures per capita and issues of poverty. Some of these attributes may comprise independent variables for individual members like age, gender, marital status and also such factors as household size, access to assets etc. The key characteristics of the analysis were to detect the factors that explain the food insecurity circumstances of smallholder farmers' households and also to determine how these issues influence the household poverty risk. It is noted that the poverty of smallholder farmers is a very intricate issue, which is a product of both household and farming characteristics. Usually, a bigger family size has a significant relationship with a much bigger risk of poverty.

As can be noted from Table 4.15, the coefficient of the household size is negative, implying that it has a negative influence on food security. When the number of dependents is increased, household food security is deplorable and unacceptable requiring the household head to dip deeper in his/her pocket. Column 4 of Table 4.15 indicates the Wald test value that informs which model variables are contributing something very important. In other words, it evaluates restrictions on statistical parameters in terms of the weighted distance between the unrestricted approximation and its imagined value. This test is a method of identifying whether explanatory variables in the model are significant. The Wald test examines the null hypothesis about a set of parameters that are equal to some value.

The results of the study further revealed that nearly 63.7% of the respondents had family sizes ranging between 3 and 7 members and only 24.3% were food secure. It can, therefore, be established that a large household has an undesirable effect on food security. As weather variability continues affecting water availability, the government should intensify efforts on the importance of water use efficiency and support a small family size. According to food insecurity, a household assumes several actions and conclusions motivated to meet family members' needs. The importance of food security is very clear and the coping means to meet family food availability include hiring labour, depending on less favoured as well as buying cheaper foodstuff. The key limitations recounted comprised, poor access to credit (88.3%) and higher input prices (83.8%). Improving water resources use is a positive strategy for numerous reasons that include environmental safety, economic benefits, and safeguarding sustainable water resources use and management for future generations.

Farmer Learning in Smallholder Irrigated Farming

Farmer learning has become a pillar in revitalising irrigated farming techniques in the wake of climate change and water scarcity challenges. Climate-smart agriculture has emerged as a new concept in modern times. Table 4.16 indicates the measures of constructs that supposedly should not be highly related to each other and are, in fact, not found to be highly correlated to each other. As for the constructs, the convergent validity was confirmed to identify the explainable factors that are relevant to farmer learning.

Table 4.16

Discriminant Validity of Constructs

	CV	Age	Education	Learning	HH Size	Tec perf*
CV	0.731					
Age	0.278	0.723				
Education	0.237	0.617	0.866			
Learning	0.258	0.286	0.234	0.796		
HH size	0.294	0.199	0.217	0.466	0.891	
Tech perf*	0.145	0.345	0.397	0.187	0.178	0.871

Source: 2021 Research Data**.** *Technical Performance

The average value extracted as values represented diagonally in Table 4.16 is greater than 0.5. Whereas the construct reliability was proven by Cronbach's Alpha and Reliability Coefficient to be greater than 0.7 suggesting that the items have relatively high internal consistency. The discriminant validity was performed to reveal whether the variables precisely targeted the construct of interest and also to avoid measuring isolated or distinct constructs and thereby losing precision. The logistic regression yielded more perfect assessments of the likelihood of fitting into the dependent category. Not only does a logistic regression model allow an assessment of how well a set of variables envisages the categorical dependent variable and define the goodness-of-fit of the model as does a linear regression, but it also provides a synopsis of the precision of the arrangement of cases, which can be of benefit.

According to Rogers (2003), the adoption of innovation is associated with the innovation-decision process through which a person traverses from the initial awareness of the presence of a new technology that may solve the challenges and problems being faced to forming an attitude or perspective to accept the utilisation of the innovation. In other words, in deciding to either accept or reject the innovation by implementing the new ideas and confirming the relevance of making an innovation decision. The factors that a household could base to decide whether to participate in learning were quantified using the binary logistic regression approach. Pohlmann and Leitner (2003) suggested that this method assesses the likelihood of events as a function of a set of explanatory variables that are assumed to control the effect or result or outcome. Those variables that have been noted to be significant have been identified by “asterisk”.

Farmers' Attitudes and Intentions to Engage in Water Use Efficiency Novel Tool Tests

Globally, facts acknowledge that rainfall has not, of late, reliably met crop water needs, a situation that has been worsened by climate variability and change (Tamburino, et al., 2020). People are more willing to employ a new technology after they observe it to be of high value in relative advantage, simple and easy to use, and extraordinary in trialability. Perceptive obstacles of farmers who are hesitant to use new technologies cost their households enormous benefits in terms of crop yields and revenue. It is acknowledged that in emerging countries, such as Malawi, many smallholder farmers still use archaic, inefficient and unsustainable approaches in irrigated farming. Besides, the adoption of innovative technologies remains an intimidating and challenging issue (Erokhin et al., 2024; Muyanga et al., 2020). To appreciate and assess farmers' attitudes and their plans towards sustainable irrigated farming practices such as crop productivity improvement and increased water use efficiency, based on principal component analysis.

Farmers' attitudes towards enhancing crop yields and increasing water use efficiency are regularly intricate and can differ based on factors like access to technology, awareness about water-saving practices, and also perceived threats linked to adopting new practices (Levidow et al., 2014). Smallholder farmer's attitude towards a new technology significantly influences technology acceptance and adoption because it forms their perceptions, opinions, and readiness to embrace new ideas that ultimately can persuade their decision-making processes and behaviours. Considering the inherent uncertain nature of agricultural production because of several stresses, a farmer's risk attitude might be one of the persuading issues linked to decision-making to adopt a new technology and improve farming practices in sustainable agricultural growth (V. Patil & Veettil, 2024). Nevertheless, most smallholder farmers generally value the importance of improving crop yields putting less emphasis on water resources conservation and increasing water use efficiency. Table 4.17 indicates smallholder farmers' attitudes about improving crop production and increasing water use efficiency and also their intentions to apply these practices in their irrigated farming activities.

Table 4.17

Farmers' Attitudes and Intentions to Adopt Sustainable Agricultural Practices

Quality	Sign	Crop Productivity				Water use efficiency				
		Mean	Freq.	%	Order	Mean	Freq.	%	Order	X^2
Attitude	Positive	0.78	65	78	1	0.69	52	63	1	.021**
	Neutral	0.46	10	12	2	0.44	23	28	2	
	Negative	0.27	8	10	3	0.31	7	9	3	
Intentions	Positive	0.75	60	72	1	0.67	54	65	1	.017***
	Neutral	0.45	13	16	2	0.45	18	22	2	
	Negative	0.31	10	12	3	0.29	11	13	3	

Statistical significance levels: ** $p \leq .01$; *** $p \leq .001$

Factors Impelling Farmers Learning to Conserve Water Resources

Participation in learning is believed to be an organised engagement of a considerable number of smallholder farmers, in various activities to achieve their challenges and problems, fulfilling the intimacy notion, that boosts the beneficial outcomes (Dioula et al., 2013). It continuously fluctuates and relies upon the experience in which it takes place. Failing to use water prudently can ultimately lead to a shortage of an adequate water supply, which can have severe consequences on crop productivity and household revenue. In this vein, farmer learning is an important activity that aims to advance water resources management, crop productivity and ultimately household income. The research was crucially carried out to ascertain some factors involved in the variability of farmer learning and participation. Those farmers who acknowledge that water availability is becoming scarcer due to climate change affecting food security and household welfare will be part of offering themselves to learn new methods of water application through the use of simple monitoring tools that an illiterate person can understand.

Agriculture has largely been observed as the men’s activity with little or no interest by women (Darko et al., 2016). Access to agricultural extension delivery services is considered as imperative and relevant to realizing agricultural growth, poverty reduction, and solving food insecurity (Feder et al., 2011). A country that essentially relies heavily on agriculture, the need for knowledge intensive agriculture cannot therefore be rejected. Research studies and reports from the African Continent and elsewhere have recognised that smallholder farmers, both men and women, are deprived of information and knowledge they require to enhance their livelihoods. Nevertheless, women are regarded as worse off (Mudege et al., 2017). The findings from this research revealed that gender is statistically significant rejecting the null hypothesis of no difference in information accessibility.

Household age showed that it negatively and significantly encouraged the head of the family to participate in learning new ways of water application. Besides it may be because irrigated farming is labour demanding requiring high energy. The negative sign construes that the youth are more capable of engaging in irrigated farming than the elderly farmers. Koundouri et al. (2006) reported that households with elderly farmers were less likely to adopt new irrigation technologies. The marginal influence ratified that the household head age increases by 1 year while the probability of learning would decrease by 2.12% *ceteris paribus*. Table 4.18 also shows the likely event of a farmer reducing water use increased by 7.31% as s/he imitated what was carried out on the neighbour's plot. From a farmer's behavioural perspective, the influence of spatial and relational peer effects on shaping water resource use behaviours has been ably substantiated. The findings reveal the presence of peer influences on water application behavioural imitation between spatially and relationally neighbouring farmers through interactions and observations. The analysis of relational proximity's role in information diffusion and knowledge spillovers has a well-established history (Genius et al., 2014).

Extension delivery is perceived to be essential as a result of water scarcity. Farm visit and inspection by extension delivery staff is decisive because it allows the staff to observe directly the field plot conditions, appreciate and recognise some specific challenges smallholder farmers meet during. Essentially these visits influence the staff to provide tailored instruction based on the individual farmer needs thereby effectively transfer modern agricultural technologies and practices to solve the challenges being met, eventually leading to improved crop productivity and farmer livelihoods (Ragasa & Mazunda, 2018).

In agriculture development, extension staff visitation is considered positive and can have very important influences on deciding participation in learning. This action also acts as a bridge between research and practical application on the farm level. It can be concluded that farmers who interact with an extension staff are more likely to participate in learning how to use water efficiently. Awareness and support from extension staff lead to the likelihood of participating in learning. The agricultural extension participatory approach commonly focuses on the expressed needs of farmers such that their goal to participate in learning is to increase crop productivity and an improved standard of rural life. The underlying aim of any learning activity is educating smallholder farmers so that they can help themselves to improve their standards of living and also connecting them to research-based information to improve crop productivity, processing and marketing of agricultural goods and services. Since CC has come to stay, the researcher assessed the factors that would influence farmer learning in the selected irrigation facilities. Table 4.18 displays significant information concerning the marginal effects of binary estimation for factors of farmer learning participation using simple devices monitoring soil water availability and soil nutrient losses. The variable marginal influence revealed that the likelihood of reducing water application increased by 4.1%.

Table 4.18

Factors Influencing Farmer Learning on SIS

Variable	Marginal Effects	Sig.
Household head gender	−0.0008	-0.0253
Household head age	−0.0212	0.0181 **
Education level	0.0055	-0.0242
Members of family	0.0014	-0.0027
Family structure	−0.0093	0.0087 ***
Food security	−0.0449	0.0238*
Income	0.0061	-0.1647
Landholding	0.0986	0.0419***
Livestock	0.0091	-0.0071
Device user neighbour	0.0731	0.0230 *
Extension delivery	0.0569	0.0412 **
Location	−0.1324	0.0295 **
Constant	11.9445	-8.9164

Source: Researcher data 2021. Statistical significance *$p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.01$.

Monitoring Tools Efficiency Assessment

Water resources utilisation among smallholder farmers in irrigation facilities can vary depending on the type of technology used in informing them when and how much water to be applied inclusive of other factors. In this research, maize yield was measured to identify whether there were variances among farmer groups in terms of maize yield realised. Table 4.19 displays the maize yield across irrigation schemes. It has, therefore, been found out that those farmers who were using the monitoring devices to apply water on their plots had higher crop yields across the smallholder irrigation schemes. Moreover, most farmers in irrigation schemes grow maize and rice in the dry season, recognised as winter cropping to improve food security at household level.

Table 4.19

Maize Yield across Irrigation Schemes

Item	Bwanje Valley			Khamalathu			Mulunga		
No.	User	Imitator	Control	User	Imitator	Control	User	Imitator	Control
1	3.0	2.5	1.3	2.7	2.3	1.9	2.3	2.1	1.9
2	2.7	2.1	1.7	2.4	3.1	1.7	2.9	2.1	1.7
3	2.8	2.3	2.1	2.8	1.9	2.1	2.2	1.8	1.3
4	2.5	2.2	1.9	2.5	2.7	1.7	2.7	2.6	1.6
5	2.9	2.4	1.8	2.7	1.9	1.9	2.4	1.9	1.9
6	2.7	2.6	1.5	2.6	2.7	1.6	2.3	2.4	1.7
7	2.6	2.7	1.6	2.9	2.1	1.8	2.8	2.6	1.8
8	2.1	2.5	1.9	2.5	2.8	1.9	2.6	2.3	1.5
∑	21.3	19.3	13.8	21.1	19.5	14.6	20.2	17.8	13.4

It has been found from the analyses that having a plot neighbouring someone using soil water and nutrient monitoring devices had a positive and significant effect on the household's food security at a 10% significance level. Social networking vis-à-vis interaction (farmer-to-farmer) is a pertinent way of getting relevant information. The results about tool efficiency assessment were performed using Analysis of Variance (ANOVA) to compare means of the three farmer groups in each of the selected schemes to determine if there are any significant changes in maize yield between them

Tables 4.20 to 4.22 provide the results of the analyses. As can be seen in these tables, the p-values are less than the alpha value (α), therefore, the null hypotheses (H_0) are rejected in each case. Some of the maize yield averages are considered to be unequal either high or low and post hoc analyses were done. A post hoc analysis was used to detect which specific farmer groups significantly vary from each other after an initial ANOVA test. The issue is to identify significant overall effects to allow pinpointing where the key differences lie by further comparing between groups (Rafter et al., 2002). Since the alternative hypotheses were accepted in both situations, the data were subjected to Tukey's Honestly significant difference (HSD) to identify which means are different and the averages of the following pairs are significantly different: User against Control as well as, imitator against control. The maize yield averages in Bwanje Valley Irrigation Scheme of the following pairs are significantly different: **x1-x3**, **x2-x3**. Similarly, for Khamalathu of the following pairs are significantly different: **x1-x3**, **x2-x3**. The results for Mulunga are also the same showing pairs **x1-x3**, **x2-x3** to be significantly different. It can be concluded that maize yields for user group against the imitator group are not significantly different in all cases. From the data presented in Tables 4.20 to 4.22, one way ANOVA tests were performed to test the hypotheses of whether there were no differences in maize yields among the farmers groups in each of the smallholder irrigation facility.

Table 4.20

One Way ANOVA Test for Bwanje Valley Irrigation Scheme

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	2	3.7708	1.8854	30.8724	5.585e-7
Error (within groups)	21	1.2825	0.0611		
Total	23	5.0533	0.2197		

Table 4.21

One Way ANOVA Test for Khamalathu Irrigation Scheme

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	2	2.8675	1.4338	16.7971	0.0000
Error (within groups)	21	1.7925	0.0854		
Total	23	4.6600	0.2026		

Table 4.22

One Way ANOVA Test for Mulunga Irrigation Scheme

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	2	2.9733	1.4867	22.2207	0.0000
Error (within groups)	21	1.405	0.0669		
Total	23	4.3783	0.1904		

Maize Yield Analysis

Improving smallholder farmers' productivity is acknowledged as a key element to lessen poverty and increase food security globally generally and Malawi particularly. Staple crops that include maize have been the attention of many investigations and the target of many policy interventions around the world. Maize yield analysis comprises measuring volume of maize produced and detecting factors that affect yield. Notably, maize is the main staple crop in Malawi and accounts for 92 percent of the total cereal grains area. However, over the years, its productivity has not improved due to CC and other issues like loss of soil fertility, area for farming etc.

The share of households that produced maize in Chikwawa district was lower than in Dedza district, 60 and over 95 percent respectively. The majority of farmers in the selected irrigation schemes stated that they grew maize for both food security and revenue if the harvest is good. They also reported that they sell maize as whole grains in 50 kg bags. Furthermore, it was noted that majority of smallholder farmers used recycled maize seeds (73.9%) due to high prices of seeds. Figures 4.16 to 4.18 show boxplots for the maize yield of farmer groups in the three selected smallholder irrigation schemes. The researcher used box plots to demonstrate and make statistically vigorous comparisons between the smallholder farmer groups beyond just only looking at the boxplots and to account for increased chances of false positives when examining many groups at once. They show dispersion of points present within a dataset, giving a good suggestion of outliers and how symmetrical the dataset is. Moreover, boxplots are essentially useful for evaluating rapidly the position, spread, and equilibrium or lopsidedness of a data set, and for allowing comparisons in two or more data sets (Pallmann & Hothorn, 2016; Pierce & Chick, 2013). A boxplot demonstrates the median, the quartiles, the range of values of collected data and any outliers that may be present. It provides a clear representation of all characteristics that the data includes and, permits a graphic appreciation of whether there is or no lack of symmetry. Importantly, box plots are used to display distributions of data values, exclusively when comparisons between multiple groups are required.

The figures below provide graphic illustrations of the farmer group distribution and also indicates the likely presence of outliers. The data shows that the groups are almost similar as the variation is not too extreme. Specifically, the difference between the group sampled averages of maize yield for some groups are large enough to be statistically significant.

Figure 4.16

Maize Yield Distribution at Bwanje Valley Farmers' Field Plots

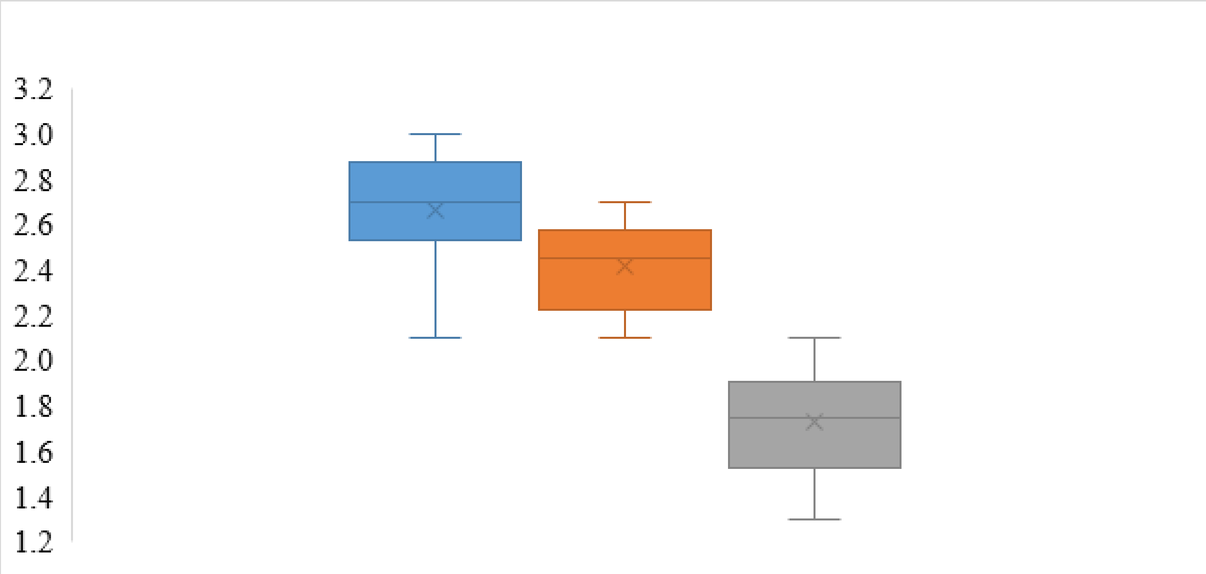


Figure 4.17

Maize Yield Distribution at Khamalathu Farmers' Field Plots

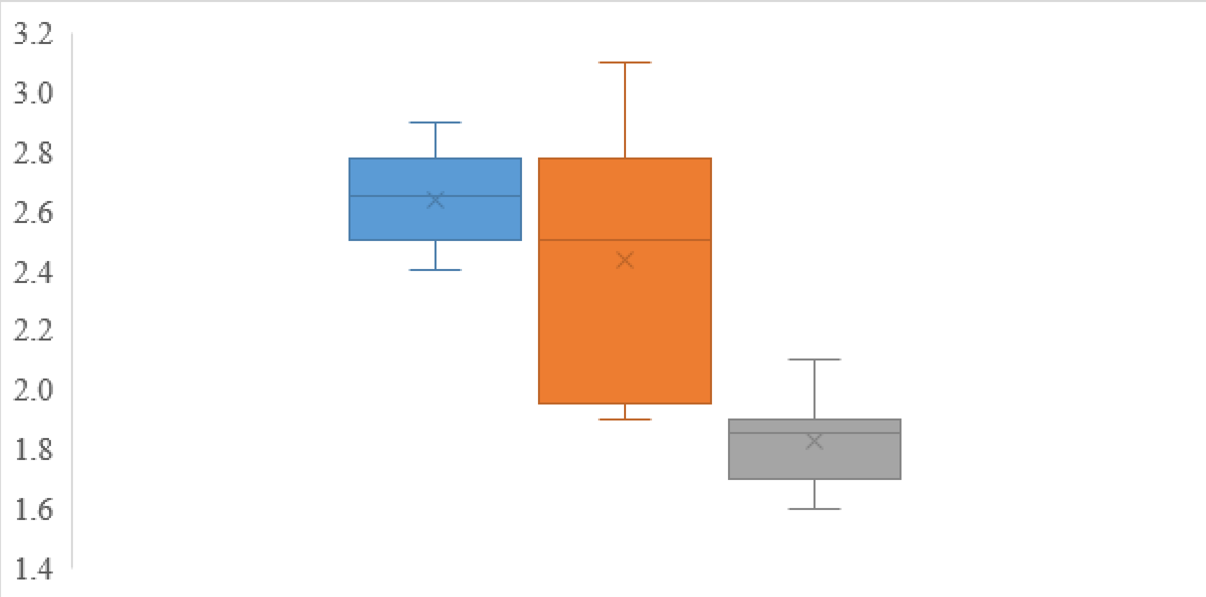
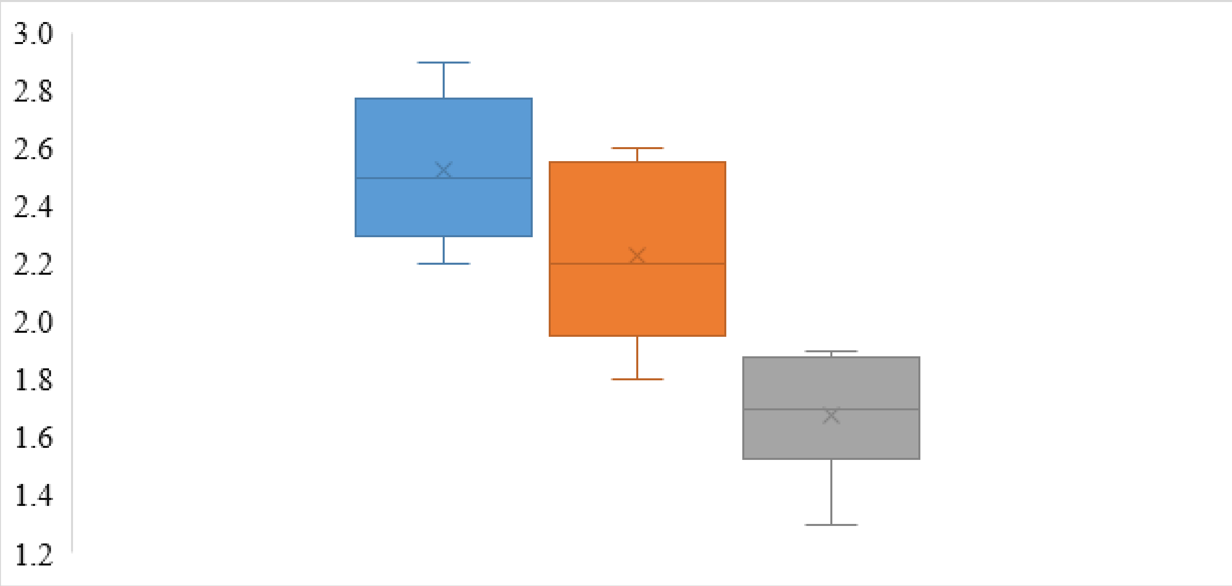


Figure 4.18

Maize Yield Distribution at Mulunga Farmers' Field Plots



Farmers who learn from other farmers can gain in many ways, including increased crop production, how they can adapt to climate change as they copy what others are doing with water application. Water conservation, an important factor, during this period when water scarcity is on the increase, farmers can only apply water when and how much is needed. The p-value of 5.5851e-7 [p (x ≤ F) = 0.999999] for Bwanje Valley signifies that the chance of Type1 Error (rejecting a correct H0) is very small 0.000056%. The smaller the p-value the stronger it supports the alternative hypothesis (H1). A Type I Error, an alpha error, is a statistical error that arises when a null hypothesis rejected when it is actually true. The results are the same for all schemes. The maize yield for the control group is different, from the other groups, meaning that the monitoring devices changed the mindset of the imitators and they noted their importance in influencing crop yields.

A gross margin analysis (GMA) was carried out to evaluate the profitability of maize production in the irrigation schemes. GMA is computed by deducting total variable costs from the income earned from selling the farm products. Table 4.23 presents GMA for maize yield for the farmer groups. The data in the table is from Bwanje Valley Irrigation Scheme.

Table 4.23

Gross Margin Analysis for Maize Yield

		Input Costs		
Farmer Group	Type of Fertiliser Bought	Bags	Price per Bag	Total Cost
User	NPK (23:21:0+4S)	4	38000	152000
	Urea (46%N)	3	38000	114000
Imitator	NPK (23:21:0+4S)	3	38000	114000
	Urea (46%N)	2	38,000	76000
Control	NPK (23:21:0+4S)	2	38,000	76000
	Urea (46%N)	1	38,000	38000
		Revenue		
Farmer Group	Maize Quantity Sold (Kg)		Price	Amount
User	2835		175	496,125
Imitator	2317		175	405,475
Control	1613		175	282,275
		Profit- Loss Assessment		
User	496,125		266,000	230,125
Imitator	405,475		190,000	215,475
Control	282,275		114,000	168,275

Based on GMA for maize plots, it has been ascertained that the value of production is the highest for farmers using the monitoring devices followed by imitator farmer group and lastly the control group. Comparing Table 4.23 with Table 4.19, it can be observed that the yield of maize used for calculations in Table 4.23 are slightly different due to the fact that different farmer plots were used to evaluate profitability of maize by the three different farmer groups The calculations are from Khamalathu Smallholder Irrigation scheme. It can, therefore, be noted that the farmers that were using the monitoring tools realised the highest profit followed by the imitators and the control group had the least. The difference between the user and imitator farmers is not huge. The conclusion to be drawn is that the monitoring devices are relevant to improve household income.

Land in the schemes appears to be one of the most important factors of crop production. Most of the farmers are allocated 0.4 hectares on which they plant maize, rice and other crops. According to FGDs and opinion leadership consultation, customary, gift, rented and shared cropping lands are common farming practices in the schemes. Rented and shared cropped lands are generally conducted on a contractual arrangement basis as the harvest is shared with the owner at the end of each irrigation season. This arrangement happens when the owner of the land cannot cultivate due to other circumstances beyond his and/or her control. Typically, the contract may be for a short period.

Seasonal Crop Water Use

From the discussion with the farmers and scheme management committee, it was noted that farmers' plots were initially irrigated with 0.18 m (180 mm) before planting in Bwanje Valley Irrigation Scheme. This was done to guarantee that the soil profile was adequately supplied with water and was wet. Water delivery to farmers' plots was based according to the agreed quantity per block.

A Parshall Flume was used to determine the quantity of water supplied to the farmer's plot. The quantity applied was calculated using the Formula $\mathrm{Q} = \mathrm{KH}_{\mathrm{a}}^{\mathrm{n}}$ for 15.24 cm Parshall Flume. Time was taken to completely irrigate each plot. The amount of water applied was computed in m^3 and changed into depths by dividing with the irrigated plot area (m^2). The description of the formula is as follows:

Where: Q = Free flow rate in $m^3 s^{-1}$,

K = Flume discharge constant varying with flume size)

Ha = Depth at point of measurement in metres,

n = Discharge exponent depending on flume size

The values of K and n are obtained from an empirical table based on the flume throat size. The time taken to irrigate the whole plot was also recorded. The recorded time was then translated into seconds to get the discharge Q in $m^3 s^{-1}$ to get the volume of water in m^3.

Photo 4.1 Parshall Flume Used to Measure Water Supply into Farmers' Field Plots

The measurement of water was to check what the farmers were saying about the beneficial aspects of using the devices. The required irrigation water supply per application (V) used the following formula:

V = CU x In x A x10 /IE .... **Equation 4.16**

Where: V = Volume of water irrigated per application (m^3); CU is daily consumptive use (mm); In is irrigation interval in days; A is irrigation area in hectares and IE is the irrigation design efficiency in per cent. It was measured that the volume of water irrigated per application was 0.61 m^3 on a 30 x 30 m area with a measured 58% irrigation efficiency.

Mixed-Methods and FGDs Findings

Tashakkori and Creswell (2007) observed that at its most fundamental level, mixed-methods research discusses research in which scholars use both qualitative and quantitative approaches in a particular study. During the field survey held in all the selected irrigation schemes food security, infrastructure management, water shortage, institutions and institutional arrangements and other issues that are also related to the marketing of crops were discussed. A question was asked: "How do you perceive the relevance of the device use in terms of yield of maize?"

One of the device users Ivesi Amosi from Bwanje Irrigation Scheme in Dedza District responded that her family harvested 3.4 tonnes of maize per hectare against less than 1.2 tonnes per hectare before using the devices. She further noted that her family had adequate food to last for a year compared to when the devices were not available. Besides, she was able to accomplish some chores because she had more time at home than to irrigate her crops. The above mixed-methods approach allowed the integration of qualitative research and qualitative data with traditional epidemiological and quantitative methods of research to facilitate translation.

When a question about the changes in household income, Ivesi Amosi reported that she sold half of the maize and realised about MK266,039 which was equivalent to US$266 (Photo 4.2 below). Richard Mose from Khamalathu Irrigation Scheme had a better harvest of maize that earned his household MK468,980 (about US$ 524). He also noted that his maize yields increased from 1.95 tonnes per hectare to 3.2 tonnes per hectare. These results have been calculated as most smallholder farmers do not willingly provide the actual incomes they realised. It was also noted that there were gender differences in their observation of household changes in income according to the narratives and were not obscure from their status which according to the researcher's experience detected truthful against false narratives.

Photo 4.2 Respondent Interviews at Bwanje Valley Irrigation Scheme

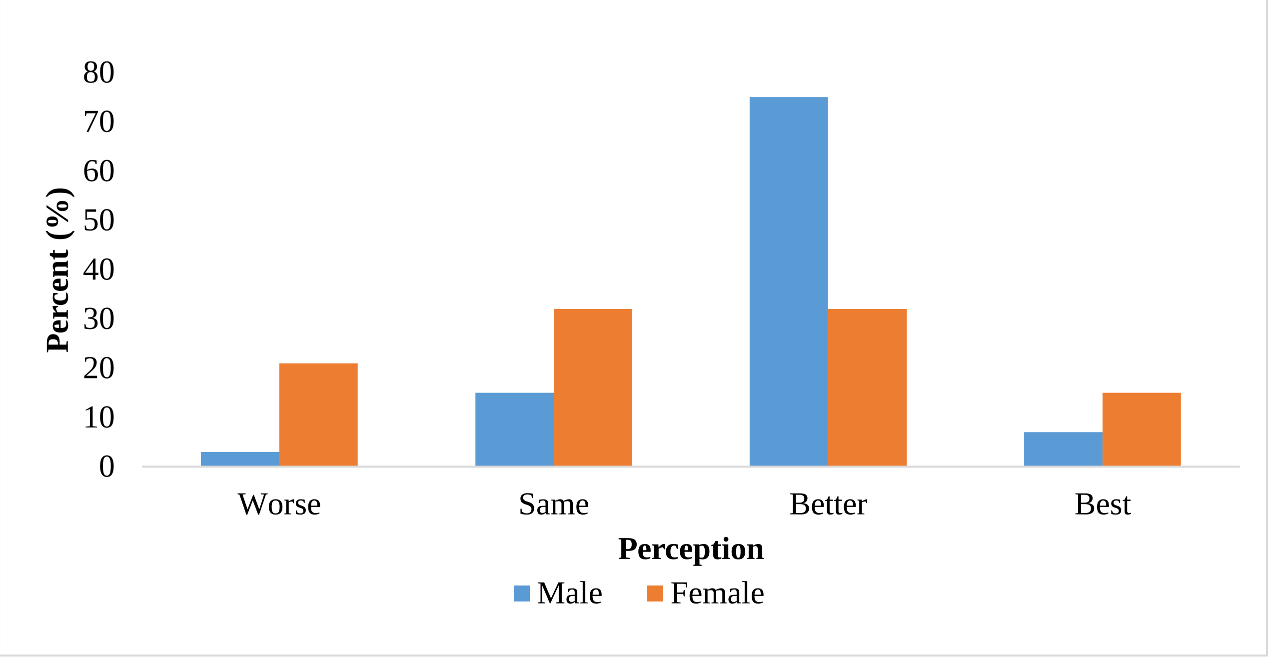
As is always the case, there is ample evidence indicating that there remains an inconsistency between male and female farmers' contributions to agriculture and the profits they accrue from it. Female farmers provide more labour to agricultural production than male farmers. On the other hand, their agricultural productivity remains worse than that of males and they are generally put aside from having decision-making power on issues that influence their economic benefits (Ngoma-Kasanda and Sichilima, 2016). Despite the fact female farmers frequently contribute a substantial share of agricultural labour, however, the amount varies by country and region, for instance, in SSA, women contribute between 30 and 80 percent of agricultural labour, depending on the country.

Contribution of labour provided by female farmers is in the range of 50–70 percent of agricultural tasks in Malawi. Whereas a substantial share of women in Zambia, around 78 percent contribute to agricultural labour (Djurfeldt et al. 2019; Khoza et. al.,2022; Tagbaru et. al., 2021). Nonetheless, information is totally different in smallholder irrigation schemes when it comes to changes in welfare. Female farmers face numerous challenges and problems compared to male farmers, including lower crop productivity, less access to production resources, and unequal decision-making influence.

Results shown in Figure 4.19 shows that more female-headed (21 percent) households indicated to be worse than before, while (32 percent) remained the same. 32 percent had better income and only 15 percent was the best during the past irrigated farming season. These trends were also observed by Chilundo et al. (2020). They noted that this discrepancy needs to be thoroughly examined to recognise the underlying reasons, particularly for female farmers. The women farmers claimed that their economic circumstances had significantly worsened. Chanana-Nag and Aggarwal (2020) reported that women play vital roles in farming and rural economies globally consisting 36 percent of all agricultural work force. Figure 4.19 reveals the fact that if women can access to irrigation technologies, learning vis-à-vis training can lead to higher crop production, better nutrition, healthier, and robust communities, mainly in emerging countries. Notably, water, food, wellbeing, and women’s empowerment are closely intertwined as consistent water access offers better readiness and stability of food provisions.

Figure 4.19

Gender perception concerning irrigation proceeds



After the household interviews, FGDs were held with smallholder farmers comprising scheme managers, irrigation committees, water distributors and local leaders to confirm unclear and confusing factors related to water resources management, mainly regarding the frequency of water application and whether there had been a change in crop productivity increment and change in wellbeing at the household level. To assess any issues related to crop productivity and incomes interviews and discussions were held with 15 individuals in each selected irrigation scheme.

Lessons have been learnt from all the selected schemes that most farmers are emulating what those farmers using user-friendly tools vis-à-vis soil water and monitoring devices are doing. Farmer learning is increasingly taking place in water resources management even though actual training has never been provided to non-users. However, during meetings they share ideas and that is where other farmers are encouraged to change watering application schedules. Others have been applying water on their plot subconsciously regardless of the soil condition and crop water requirement. From the FGDs held, it was concluded that the monitoring devices have and continue to change how much and when to irrigate the crops. What most of them narrated was about the availability of user-friendly devices and their cost. Recognising that SIS have to be revitalised, and farmer learning, innovation and assessment concerning how water resources are managed are essential requirements to enable sustainable transitions as climate change and variables are presently critically affecting crop yield (Mwadzingeni et al., 2022).

Findings of Research Questions and Hypotheses

Research questions formulated to undertake an investigation are essential elements that guide how the research should be conducted. They are characteristically succinct, resolute and arguable providing a flawless path for research. It determines precisely what to find, and what is or is wanted and provides a well-defined emphasis on the results and purpose (Holley and Harris, 2019; Thomas, 2017). This research study was to assess how water resources are used by using devices that make irrigation scheduling very easy and interesting. It is well known that the soil holds water after it has been applied (Yu and Kurtural, 2020; Martínez, et al., 2016).

For bumper crop yields, a farmer is encouraged not to apply too much water using the chameleon and also the bucket of the waterfront detectors should not overfill to allow nutrients to be within the root zone and if it overflows this would be a waste and encourages leaching of nutrients (Kana, 2016). Besides, the farmers should not allow the bucket to get empty to avoid stressing the crop. It has been observed that stress in farming decreases crop productivity and profitability which results in household food insecurity and well-being (Herrera et al., 2021; Venkateswarlu et al., 2011). To competently conduct this research, three questions and five hypotheses were formulated to assess how smallholder farmers on some selected irrigation schemes in the country benefitted from using the chameleon and waterfront detectors to improve crop yields, increase water use efficiency and household income.

Participation in Learning New Farming Practices Using Novel Technologies

Participation in learning new methods and practices has become a widely debated issue in irrigated farming due to climate variability and water scarcity challenges. Climate-smart agriculture, though a new concept in modern times, can become relevant if it contributes to lessening poverty and improving food security. Farmer participation in learning can, therefore, be described as a pathway in the right direction of agricultural development and food security that is based on three pillars namely increasing productivity and profitability, improving livelihoods resilience, and reducing greenhouse gas emissions into the atmosphere that is negatively affecting ecosystems (Nagargade, et al., 2017).

Chameleon sensors and waterfront detectors were provided to 20 farmers in each of the selected schemes and were significantly inadequate based on the number of farmers in the schemes. The Chameleon sensors were usually checked once or twice per week by extension assistants in the presence of the farmers. Scheme meetings were held once a month with farmers (both using and not using the devices), scheme management and project assistants to debate the information collected. The colour patterns exhibited by the chameleon devices and the nitrate readings formed the basis of interaction and learning how to manage water resources. After an exhaustive meeting and reaching a compromise, the farmers then adjusted their water application practices based on what they learned from the results obtained from the devices.

The interaction between smallholder farmers involved in irrigated farming activities having access to and using water monitoring devices (acting as learners) and those without access (imitators) within the same scheme is advantageous to the earlier than the latter as one farmer lamented. Farmer learning in an informal setting supports new technology acceptance, adoption and diffusion being promoted through the formal system process (Sahin, 2006; Rogers, 2003). Asking the respondents how they perceived the role of the devices in water resources management, the finding revealed that there was a lack of time to interact with those using the devices, but there was also arbitrary resistance from the imitators possibly due to the selection criteria besides shortage of resources and ease of technology availability (Areed et al., 2021). Some farmers claimed the existing extension services system favoured affluent farmers discouraging resource-poor farmers from participating in learning how to manage scarce water resources. The proposition that there is no significant relationship between socioeconomic characteristics and farmer learning to improve water resources management and increase water use efficiency was therefore rejected.

Seasonal Crop Water Consumption

Seasonal crop water use can be explained as the variation in water consumption by a crop in a season (Biemans et al., 2016). The 22.86 (9-inch) Parshall Flume was used to measure water flow being applied on a farmer's plot whose formula is $Q = KH_a^n$. For this research ($0.393*H_a^{1.53}$). Three selected plots from users and imitators were supplementary irrigated and time taken to completely irrigate each plot was recorded to calculate volume (m^3) of water applied and was subsequently converted into depth by dividing the irrigated area (m^2). The depth of water was found to be 231 mm for imitators and 195 mm for user. From these results it can be acknowledged that the users used less water and their yields were found as 1.98 t/ha for users and 1.73 t/ha for imitators. These results are from Khamalathu and were also reported in Table 4.26.

Household Food Security and Welfare

The 1996 World Food Summit deliberated on the food security phenomenon affecting people globally. The summit agreed on the following definition of food security it happens when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Based on the definition, this research formulated the following question: "Do farmer-friendly soil water monitoring tools explain farmer households' benefits of their use?" The Department of Irrigation with donor partners to revitalize irrigated farming in Malawi, introduced novel soil water monitoring tools to improve soil moisture holding capacity and nutrient retention dynamics in the root zone for suitable irrigation and nutrient leaching management. This research hypothesised that farmer learning under various institutional arrangements does not influence water resources management and water use efficiency. A supporting hypothesis was that farmer learning is related to overall household food security and income.

Kusangaya et al. (2014) confirmed that climate is changing in southern Africa in which Malawi is located. The region is semi-arid or arid and periodic droughts are a frequent phenomenon. Besides, this is exacerbated by water resources scarcity and poor management of SIS. The water shortage challenges for operational and effective agricultural production pose significant negative consequences on the overall population, more so in rural areas. These areas are where the rural majority are engaged in farming for their livelihoods both for subsistence and income. *The monitoring devices* have been designed to fit *the* mental capacity of smallholder *farmers who are in most cases illiterate so that they provide* instant output prompting taking immediate action (Conn, 2017).

These methods were envisioned to increase national economic growth by enhancing crop yields and household incomes thereby revitalising the SIS into prosperous communities and sustainable irrigation schemes (Nhemachena et al., 2018). Regarding scheme management and how farmers are organised, it was found that some institutional arrangements are formally communicated to the farmers like the water user's association regarding how water supply distribution from rivers should be managed within their schemes and cooperatives dealing with crop marketing. This finding agrees with what Kangile (2015, p. 3) claimed when he investigated the efficiency in the production of smallholder rice in Pwani and Morogoro Regions, Tanzania. Both cooperatives' and water users' associations on SIS are among the mechanisms that characterise collective management facilities by farmers with some government involvement and external backing. Thus, they are established to bring farmers together to manage a collective irrigation system that promises high profitability at the household level (Silvestri et al., 2015).

Regarding the second question, what benefits do user-friendly soil water and nutrient monitoring tools have to improve productivity and profitability in SIS? Its subsequent hypothesis was that farmer learning is related to overall household food security and income from SIS. Different studies have been carried out that have indicated a positive effect of small-scale irrigation on food security. Kilpatrick (2011) suggested that better water management to avert climate variability challenges is essential for smallholder farmers in Malawi to increase crop productivity and food security. Mangison (2008) alluded to the fact that 70% of all adopters were food insecure before accepting and adopting new irrigation technologies to improve food security in Malawi. Since farming is done by elderly people they need to experience and participate in the learning process. Experiential learning involves a learning process whereby the learner, in this case, farmers learn by doing and in doing so they can reflect on what they are doing and gain the requisite experience.

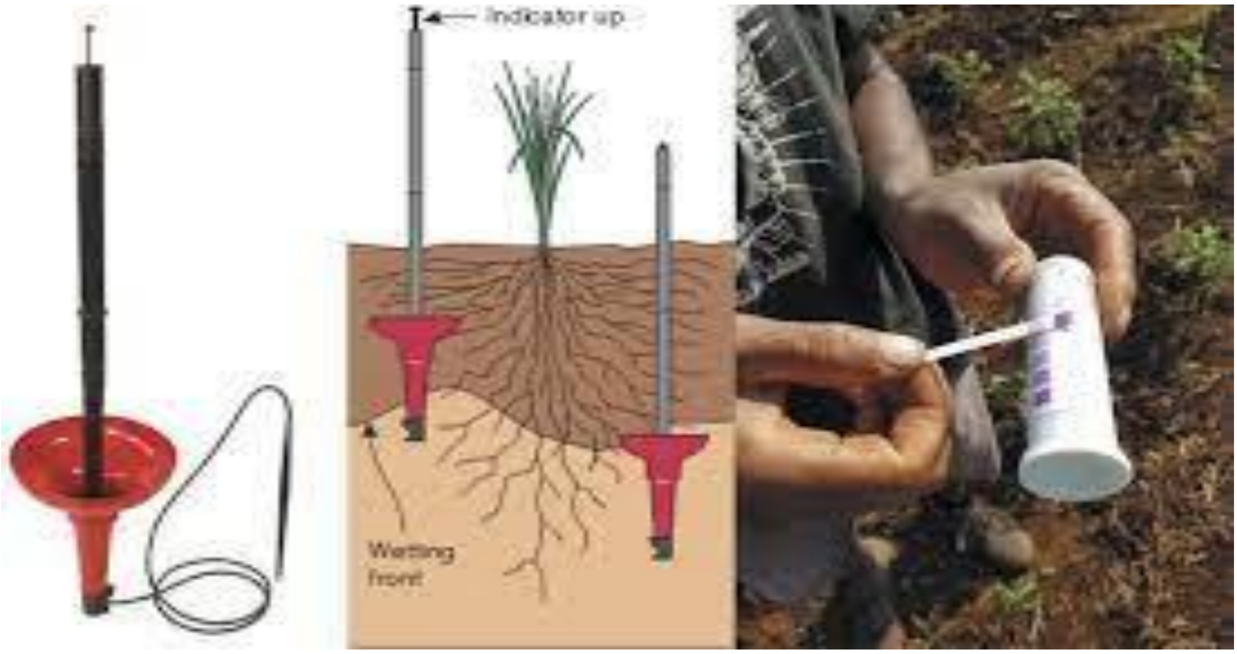
Nearly 92, 89 and 82 percent of the farmers interviewed who were using the devices in Bwanje Valley Irrigation Scheme, Khamalathu and Mulunga respectively recounted that they participated in soil water content monitoring, determining when to irrigate based on the colour shown on the Chameleon device and also checking whether fertiliser applied was being leached. Figure (4.20) demonstrates how farmers determined leaching of fertilisers from water samples from the WFD. However, such monitoring activities were initially demonstrated to them by the Field Extension Workers who were employed to convey these techniques to smallholder farmers. Although only 20 smallholder farmers were provided with these monitoring devices for the each of three schemes mentioned above. This has resulted in farmer learning, revealed by the changes in decision-making and action concerning how farmers have engaged with others and their awareness and changes to the manner water is applied.

A wetting front detector (WFD) is used to detect the depth to which water has reached and can be used as to manage water application. The WFD is a funnel-shaped device buried underground and senses when water wetting front has arrived at a precise depth (Figure 4.20). It necessitates a farmer to irrigate easily and accurately. This is because soil retains water like a sponge. Everyday crops extract some water through roots and is transpired through leaves.

Some water evaporates from the soil surface known as evapotranspiration (Alfieri et al., 2020). Essentially, WFD helps farmers to imagined what is happening within the root zone when water has been applied to soil.

Figure 4.20

Wetting Front Detectors at Two Soil Depths Ground Facilitating Nitrate Testing



Source: Moyo et al. (2020)

Some farm families have reduced irrigation time and frequency because they know about the importance of the devices as well as the relevance of what the devices determine and their uses. Besides, the households have made significant adjustments to water application due to learning from the colours shown by the Chameleon. Farmers have a perfect understanding that the devices do help improve irrigation water resources management and importantly apply less water on their plots, therefore, increasing water use efficiency. The devices show the soil water content in the root zone and facilitate irrigating at the time when the crop is under stress and needs water, in fact using available water more wisely. From the above, it can be concluded that the second hypothesis of the second question supports that farmer learning is related to overall household food security and income.

Synthesising Quantitative and Qualitative Findings

The question, how do quantitative data results (question 2) support or refute qualitative data results (question 1)? Was formulated to triangulate the findings from question 1. The purpose of conducting qualitative research could be seen to be closer *to problem* generation sometimes called problematising than *problem*-solving. Proficient interviews are a familiar qualitative interview approach that frequently aims at acquiring information about or exploring some detailed, specific and immediate intervention (Busetto et al., 2020; Jamshed, 2014). Considering quantitative research, its purpose is to realise better knowledge and appreciate the social worldview. Several scholars use quantitative approaches to discern situations or events that influence people's behaviours (Davis et al., 2015).

Quantitative research creates unbiased information and data that can be unmistakably communicated through statistics and figures. It is a method that measures variables, evaluates them and reports interactions amongst the investigated variables via a numerical structure. Its objective is to appreciate, explore, and define to make imminent expectations of technology. Accordingly, after understanding the calculated figures and statistics, it becomes informative for clients vis-à-vis smallholder farmers to make appropriate changes to their farming systems. It deals in impartial, rational, and statistics and puts its emphasis on convergent perceptive, comprehensive and invariable data (Bhasin, 2008). Similarly, it is vital to gauge what is of value to the farming actions.

In this research, the measures required to emphasise the key water resources management strategies like conservation of fertiliser application in the root zone and also reducing water application; accordingly, the smallholder farmers on the irrigation schemes can take action. Maize crop was grown in all the selected schemes, however, the distribution of plot sizes differed. At the Bwanje Valley Irrigation Scheme, farmers were allocated 30 x 30 m plots to grow maize. Because food insecurity is rampant in all the areas, farmers were advised not to sell green maize even though they fetch higher prices and income. It was therefore decided that the project assistant collected information on the maize yield to compute the yield per hectare. Based on the above, an analysis was conducted to identify factors that influence crop productivity and welfare. The results indicated that 55–70% of the households reported that their food security, nutrition (healthy), income and ability to pay school fees for their wards improved significantly as they were better, or better than at the beginning of the water soil water monitoring project. However, some reported that they never saw any changes or differences as can be seen in Table 4.24 below.

Table 4.24

Observation of Variable Household Changes (Percent of Respondents) N = 83.

Attribute	No Difference (%)	Better (%)	Best (%)
Food security	15	12	73
Nutrition and health	12	21	67
Earnings	13	29	58
Ability to pay school fees	14	21	65

Considering nutrition and health as well as the income the households realised, these were very obvious but much of interest was the ability to pay school fees and purchase school uniforms for their children. Education is very important and Sustainable Development Goal 4 aims to ensure inclusive and equitable quality *education* and promote lifelong *learning* opportunities for all. Better and more education provides a conduit for excellent farming products for future generations as well as better livelihood opportunities for those not involved with farming.

Respondents' Perception of the Use of User-friendly Devices

Participants described the concept of water user efficiency as new and not measuring the quantity of water used to produce crops. This was, however, revealed in the manner in which they knew when to apply the water. Local knowledge of their soil condition helped even though they did not know much about how water was measured using the devices. It was substantiated by the Parshall Flume during the survey by referring to good or bad water application. The abstract views of participants at Bwanje Irrigation scheme during the FGD session on how they understood water use efficiency and crop productivity. Most of them said that the water use efficiency concept was not new. Ordinarily, farmers questioned whether there was progress either forward or backward in crop yield. The productivity of water was explained by referring to water application based on soil conditions. Moreover, water productivity is recognised as the crop harvest obtained after requisite water use. Water user associations were appraised in championing proper water use as crucial in crop production and are a stake in poverty alleviation and food security improvements. However, farmers do not measure the volume of water used for crop production.

Farmers from Khamalathu Smallholder Irrigation Scheme had a different understanding of the water use efficiency was new and they heard it for the first time when they were interrogated. The imitators suggested that it is related to the application of less water for higher crop yield. Some said that even though the soils have been depleted of fertility the devices allowed the fertiliser applied was not lost but remain within the root zone.

The water use efficiency concept was presented to farmers from Mulunga Smallholder Irrigation Scheme in Chikwawa District. Chikwawa District is in the Lower Shire Valley, and most of the soils found are of alluvial type. The district agricultural office with its partners has suggested several moderation actions for addressing the negative environmental impacts (Coulibaly et al., 2015). Some of these include enhanced soil and water resources management practices by smallholder farmers involved both in rain-fed and irrigated farming and also river catchment conservation strategy by introducing extensive land management practices as well as restoration of the riverine ecosystem through tree planting.

The soil type and structure range from deep, medium to fine textured, brown to very dark grey in colour. Their drainage differs from good to very poor. However, the likely crop failure can be attributed to soil salinisation and excessive nutrient loss. In irrigation schemes, the principal cause could be inappropriate water management practices and lack of drainage. According to Li et al. (2017), the soils in the low-lying areas in Malawi are more variable and graded largely as cambisols, fluvisols, luvisols, gleysols and vertisols. From the group discussion with opinion leaders, particularly the Agricultural Extension Development Office claimed that the district has more than ten (10) soil groups out of a total of 13 soil groups recognised in the country revealing that several types of crops can be grown in Chikwawa.

Due to erratic rainfall distribution, the respondents in the FGDs indicated that they have developed some coping strategies such as planting mixed crops (sorghum, millet and vegetables). Besides, they have been planting drought-resistant crops like sorghum and cassava and practising flat cultivation in wetland areas to increase crop yields. Some leaders indicated that they are still growing local crop varieties because they can withstand drought and early maturing crops that are being advocated by the extension agricultural staff to grow well during water scarcity.

With the introduction of the new technology that smallholder farmers have been using and some imitating due to weather variability as a cause of concern for climate change, promising results have emerged that some farmers are harvesting bumper crops. This prompted the researcher to probe further how the gender of respondents understand water use efficiency improvement brought by the use of soil water and nutrient monitoring devices. A selected number of 40 respondents from Bwanje Valley Smallholder Irrigation Scheme were asked to explain whether they understood the concept of water use efficiency and its impact. The question that was put across to the respondent in a FGD was whether water resources management was related to the gender of the person who considers food security and poverty the critical issues of the household. Or to put it in another way, the researchers wanted to identify whether male farmers show a different pattern of understanding of how water resources could be managed compared with the understanding of female farmers.

Table 4.25 shows the responses from the two groups regardless of the positions held. It was noted that females, 12 (63.2%) did not understand the concept, implying that most females were not aware of the concept of water use efficiency which might have been due to a lack of awareness and its value. Compared to male farmers the majority knew because they were the ones using the devices. The Chi-Square calculation in Table 4.25 is revealed to be 2.55. This value is less than the critical value with one degree of freedom of 3.84. So, in this case, the null hypothesis cannot be rejected. In other words, there does not appear to be a significant association between the two variables: males and females have a statistically similar perception of increasing water use efficiency. Gender is a key to defining the power, privilege and opportunities that some people have and others do not have in a society. The finding shows that equal treatment is vital to water resources management in the current situation.

Table 4.25

Gender Perception on Water Use Efficiency Concept in Percent (N= 40)

Knowledge of Water Use Efficiency for Crop Productivity					
Gender	Yes	No	Total	X^2	*P*-Value
Female	12 (63.2)	8 (36.8)	20	2.55336	1.604
Male	7 (36.8)	13 (63.2)	20		
Total	19	21	40		

The Chi-Square statistic with Yates correction is 1.604. The p-value is 0.205336. Not significant at $p < .05$.

Water resources conservation behaviour in irrigation schemes is an issue that needs to be addressed quickly and competently as a reaction to the implications of climate change and weather variability (Bhaga et al., 2020). Since one cannot conserve water when it is not available, increasing water use efficiency is therefore important. The monitoring devices as introduced in the irrigation schemes can increase water use efficiency by consenting farmers to precisely follow irrigation timetables to apply water on their irrigation plots based on real-time soil water content and nutrient levels. Following the schedules, it will ensure that crops receive and consume only the necessary water and nutrients, significantly reducing water waste from overwatering and needless fertilisation, thereby optimizing water usage (Alharbi et al., 2024; Lakhiar et al., 2024).

Advances to increase water use efficiency are required at farmer, institutional, management and policy decision-making levels. Several researchers have claimed that there is still considerable opportunity for increasing the efficiency and productivity of water use in irrigated farming (Alharbi et al., 2024; Levidow et al., 2014).

Effect of User-Friendly Tools on Maize Yield

Maize yield data was measured from 81 farmer plots. The mean yield results are used to examine the relationship of maize yield against the user groups. The results indicate that maize yield in the control variants was very low in each irrigation scheme (Table 4.26).

Table 4.26

Maize Yield Data (t/ha) Planted at Three Irrigation Schemes

Scheme	Control	Imitator	User
Bwanje	1.45	1.85	2.04
Khamalathu	1.24	1.73	1.98
Mulunga	1.44	1.79	1.87

An analysis of variance in Table 4.27 based on collected data was done to isolate the designed and understandable variation from the random and unexplainable difference. A one-way ANOVA between farmer groups was conducted to compare the effect of water use by farmer groups on maize yield (control, imitator and technology use).

Table 4.27

ANOVA Determining Food Security Status

Source of Variation	DF	SS	MS	Observed F	Required F (5%)
Treatment	2	0.55	0.273	32.617	5.14
Error	6	0.05	0.008		
Total	8	0.60			

The null hypothesis being tested was that all farmer group means are similar. Thus, the null hypothesis of equality (H_0) is $\mu1 = \mu2 = \mu3$ meaning that the average maize yields are the same for the three farmer groups. The result revealed that there was a significant effect of farmer groups on maize yield at the $p<.05$ level for the three conditions [$F (2, 6) = 32.617$, $p = 5.1$]. The sample means are significantly different from each other. The observed differences among the maize yield means could not reasonably be due to random chance alone. The result is statistically significant such that the farmer group that used the devices harvested the highest yields in comparison with the two groups. It can be concluded that using a user-friendly soil water and nutrient monitoring tool as a decisive approach to inform farmers when to apply water adequately affected maize yields and household food security.

Food Security Status between Users and Non-Users based on Socio-economic Features

Access to safe, healthy, and adequate food is a fundamental human right, with priority given to the most vulnerable people. Despite basic nutrition, food security is associated with economic stability, lasting health, women's empowerment and environmental stewardship. Food insecurity is a major challenge in Malawi particularly for smallholder farmers who rely upon rain-fed agriculture for their livelihoods. Therefore, the researcher investigated issues affecting the food security situation in smallholder households. For this study, as a food security measure, a minimum consumption rate of 2,700 kcal per person daily was used to determine household food security. Many studies conducted in the United States of America reported estimated calorie intake per day between approximately 1,500 and 3,000 (Bleich and Pollack 2010; McCrory et al. 2016 Mckinnon et al. 2019). It is noted that age, gender, and marital status are commonly reported in food security research because they are considered important sociodemographic variables that can significantly affect results across several fields, permitting researchers to detect likely patterns, biases, and disparities in the outcomes. Based on these issues, it is possible to considerate in bigger context and possible to generalise the findings. Table 4.28 displays the food security status of technology users and non-users in the selected irrigation facilities.

Table 4.28

Smallholder Food Security

		User		Non-User		Pooled	
Variable	**Range**	**FS**	**FI**	**FS**	**FI**	**FS**	**FI**
Gender	Male	13	22	21	28	35	49
		37.1	62.9	42.9	57.1	41.7	58.3
	Female	6	11	5	11	17	16
		35.3	64.7	31.3	68.8	51.5	48.5
Age (years)	20-39	9	11	7	18	20	25
		45	55	28	72	44.4	55.6
	40-59	5	16	9	21	21	30
		23.8	76.2	30	70	41.2	58.8
	>60	1	4	7	9	5	16
		20	0.8	43.8	56.25	23.8	76.2
Marital Status	Married	14	29	16	33	43	49
		32.6	67.4	32.7	67.3	46.7	53.3
	Single	6	5	3	11	11	14
		54.5	45.5	21.4	78.6	44	56

The pooled results revealed that 42% and 58% of smallholder farmers were food secure and insecure respectively. Furthermore, male-headed households were more food secure than female-headed households based on the pooled data and even across beneficiaries and non-beneficiaries. Despite the fact that women farmers are responsible for 60-80% of food production in developing and half of the world's food production, they are left out in training programmes (Njobe and Kaaria, 2015). Female farmers also experience greater challenges mainly in accessing financial support and services than male farmers.

Predicting Farmer Uptake of New Agricultural Practices

The researcher wanted to understand farmers' self-reported perception of adoption behaviour regarding the user-friendly tools across the selected irrigation schemes satisfying their needs in real spaces. Crucially, it was considered to assess the effect of intervening variables on farmer learning and adoption behaviour and also to match their influence with independent and environmental variables. The intervening variables that were considered comprise various characteristics of needs vis-à-vis efficiency misperception, need tension and need compatibility; perception in terms of prominence, advantages and disadvantages as well as knowledge acquisition in terms of awareness creation from extension or any other communication conduit. Each intervening variable's relationship with the adoption was conducted to examine the relationship between water use and the crop productivity attained.

According to Düvel (1991) efficiency misperception factor is considered as one of the intervening variables that is presumed to be the major determinant of human behaviour. It has been argued that individuals tend to overrate themselves regarding production and/or farming practice adoption efficiency (Kuehne et al., 2017). Efficiency misperception has an important influence on personal adoption behaviour because as efficiency is overrated, the lesser the problem extent or need tension becomes and consequently the smaller the incentive to adopt the recommended innovations. Three very salient factors can be identified for technology adoption which include constructive tensions, open innovation, and knowledge standardization that positively influence the pace of technology adoption. Technical efficiency which may be part of constructive tension measures the managerial skill of a farmer to accomplish the maximum level of output given a set of inputs. As such technology improves water use efficiency, addresses labour deficiencies, and makes sure that high-quality produce influences the market, making it essential for modern irrigated farming a success and sustainable. When a farmer is asked to rate himself or herself usually, they overrate themselves to impress the interviewer. Table 4.29 presents relationship between efficiency misperception and adoption of user-friendly tools across SIS.

Table 4.29

Relationship between Efficiency Misperception and adoption of User-Friendly Tools across SIS

Efficiency perception Assessment	Adoption							
	Bwanje Valley		Khamalathu		Mulunga		Total	
	n	%	n	%	n	%	n	%
Underrate	12	38.7	7	29.2	8	25.0	27	31.0
Slightly underrate	2	6.5	2	8.3	6	18.8	10	11.5
Assess correctly	4	12.9	5	20.8	5	15.6	14	16.1
Slightly overrate	5	16.1	8	33.3	6	18.8	19	21.8
Overrate	8	25.8	2	8.3	7	21.9	17	19.5
Total	31	100	24	100	32	100	87	100

χ^2 = 8.1958; df = 8; p=0.01. **Source**: Researcher data, 2021.

This has escalated the hypothesis that there is a significant negative association between the efficiency misperception and the adoption of the user tools. This was determined by asking farmers to estimate their adoption efficiency on a five-point scale. Table 4.29 summarizes the relationship between efficiency misperception and the adoption of user-friendly soil water monitoring tools after participating in farmer learning activities. The investigation was whether farmers' distribution in the irrigation schemes mainly those who knew of the existence of the user-friendly tools differed. Venkatesh et al. (2003) observed that performance expectancy pertains to an individual's perception that the utilization of an innovative technology will advance performance. In the efficiency misperception context, performance expectancy is the degree to which the existence of the efficiency misperception among farmers will improve farmers' performance using the technology. In a world of scarcity, efficiency is essential to get the most value from an available number of resources. Misunderstanding efficiency vis-à-vis efficiency misperception develops from the conviction that the query "What is efficient?" has an intent, general response so that it is just a matter of converting things over to experts.

The null hypothesis was that there is no significant difference between the irrigation schemes in terms of the efficiency perception assessment. It was found that the X^2 value of 8.1958 and eight degrees of freedom was larger than the critical P value is 0.41458. Since the calculated Chi-Square is greater ($t < 0.01$), the null hypothesis that there is no significant difference between efficiency misperception and adoption of user-friendly tools across SIS is rejected. The alternate is therefore adopted that there is a significant difference between the irrigation schemes in terms of technology efficiency. Just above 40 percent of the respondents in all the schemes overrate their efficiency of adoption when compared to a more "objective" measure or assessment (Table 4.29). This indicates that these farmers show no reason to adopt the technology as they are satisfied with their way of water application and thus, they do not have an appetite or to change their behaviour regarding water resources management.

Another important strand of information regarding technology adoption is the value a farmer puts to it. Knowledge of technology availability as well as compatibility and awareness are relevant to farmer's behaviour change. Agricultural information should, therefore, flow to farmers because of their needs, it is possible for some to change their decisions and accept use of them (Acker and Gasperini, 2009). Besides, compatibility, a variable considered in technology acceptance and adoption, discusses how sound a technology fits a farmer's principles, beliefs, and experiences. Thus, if a technology is alleged to be compatible, it means that it is likely to be accepted and adopted swiftly by a user for instant use (Beaman et al., 2016). Whereas, there are other factors that influence technology adoption, for instance, relative advantage, complexity, Triability and observability, a positive technology adoption strategy should focus on learning, management backing, and user involvement. According to Duvel (2004) need incompatibility is another need-related reason for not adopting a technology that indicates that the proposed solution, due to its increased efficiency or practice, is incompatible with the needs, desires, challenges or problems. Thus, it means it is not proper and does not fit into the mental capacity or need situation, as such it is not perceived to either have a need-related aim or a necessary means of achieving something in using it.

Since need compatibility measures whether the suggested solution fits into the need's context or whether it adds value towards the realisation of needs, this moderating variable was measured by asking farmers to guess the level of production efficiency they would have attained if they had used the user-friendly soil water and nutrient monitoring tools. It is a key factor in how rapidly an individual can accept and adopt new technologies. It denotes how sound a new technology fits with personal's values, needs, and experiences. Technology-user compatibility is relevant to adoption decisions in general. Users differ in their background, mental capacity, work style and viewpoints (Granita et al., 2021). The compatibility between the devices and farmers is therefore positively linked to use intention and perceived utility causing less cognitive discord and metal load.

Low need compatibility with a new technology can be a barricade to acceptance and eventual adoption, as it can be construed that the technology does not align with prevailing values, practices, or experiences. For instance, compatibility with values determines that the technology may not be in tandem with the values of likely adopters. Compatibility with practices may mean that technology may not suitably orient with existing operations. Whereas, compatibility with experiences may indicate that the technology does not agree with past experiences of likely adopters.

Table 4.30

Relationship between Need Compatibility and User-Friendly Tools Acceptance

Need compatibility	Acceptances and Use of User-Friendly Tools							
	Bwanje Valley		Khamalathu		Mulunga		Total	
	n	%	n	%	n	%	n	%
Low need	7	22.6	6	25.0	5	15.6	18	20.7
Compatibility	9	29.0	10	41.7	10	31.3	29	33.3
Medium need compatibility	10	32.3	8	33.3	6	18.8	24	27.6
High need compatibility	5	16.1	0	0.0	11	34.4	16	18.4
Total	31	100	24	100	32	100	87	100

$X^2 = 9.2512$; p-value = 0.159934.

The research findings on the relationship between need compatibility and use of the user-friendly soil water and nutrient monitoring devices are presented in Table 4.30 above. The proportion of farmers having more than compatibility or perceived need for the user-friendly tools fitting into the psychological perspective and ranged from 75 percent (Khamalanthu) 77.4 percent (Bwanje Valley) and 84.4 percent (Mulunga) with the highest need. The Lower Shire area in which Khamalathu and Mulunga are located receives low rainfall and this finding demonstrates the need to adopt the technology which farmers need to promote efficient water use as a way of solving water shortage due to rainfall erraticism (Maguza-Tembo et al., 2017). The farmers showed high need compatibility of technology. This finding shows a way how farmers can respond to drought experiences and awareness for better irrigated agricultural production. In this research, it was planned to assess smallholder farmers' apparent assessment of drought adaptation technologies, limitations and opportunities. The soil water and nutrient monitoring devices that farmers used compared to the irrigation schemes that did not use these devices were, therefore, perceived to be significant for all the considered performance measures.

Technology Awareness

Awareness is another pertinent intervening variable that influences the adoption behaviour of human beings about agricultural technologies (Düvel, 2004). Awareness about technology adoption concerns the knowledge and interest that can facilitate attract potential users and urge adoption. It comprises understanding the technology functionality, its wider societal influence, and its likely utility. This awareness refers to acclaimed solutions that offer optimum levels in achieving agricultural production efficiency. For example, the acquisition of a new technology affects many areas, such as fertiliser, pesticides, seed as well as water use. Current farming practices can have both optimistic and pessimistic environmental effects according to Gomiero (2016). Accordingly. water use efficiency is imperative for smallholder farmers to be aware of as it helps in reducing water wastage and therefore adapt to CC. The findings relating to the relationship between awareness and adoption are represented in Table 4.31.

According to Table 4.31, the majority of the farmers (74.4 percent) were knowledgeable of the benefits of the water use efficient devices in the irrigation systems this research study conducted. Only 25.6 percent of the farmers were not aware of the existence of the devices hence no opportunity to verify their importance. The results show that there is a highly significant positive correlation (r=0.612, p=0.000) between awareness of devices and their use, suggesting that awareness of the benefits of the devices can lead to a higher adoption rate confirming what Düvel (2004) claimed.

Table 4.31

Relationship between Awareness and Monitoring Tools

Awareness	Bwanje Valley		Khamalathu		Mulunga		Total	
	n	%	n	%	n	%	n	%
Aware	31	68.9	24	75.0	32	80.0	87	74.4
Not aware	14	31.1	8	25.0	8	20.0	30	25.6
Total	45	100.0	32	100.0	40	100.0	117	100.0

X^2 = 1.3807. The p-value is 0.501403.

For example, farmers who were aware of the device benefits ranged from nearly 69 percent at Bwanje Valley, Khamalathu, 75 percent and Mulunga 80 percent. It can, therefore, be concluded that the tools exhibited relevance in improving crop productivity and household profitability. Moreover, the significance of farmers' awareness and knowledge, their needs and use of the user-friendly soil water and nutrient monitoring tools were acknowledged in Malawi.

Awareness raising on water resources management issues pertains to influencing attitudes and social norms of farmers in such a way that their behaviour is compliant with an effective, environment-friendly and efficient use of water resources. Awareness is promoted through a social pressure towards sound and sustainable policies. Crucially awareness considerably moderates the link between water resources use to farmer's willingness to involve in eco-responsible irrigated farming activities (Rustam et al., 2020). As a consequence, modern agriculture should be practiced sustainably and responsibly to balance productivity and environmental protection.

Water-efficient practices in smallholder irrigation systems can potentially improve the economic viability and environmental sustainability without essentially reducing water usage. Innovative technologies are largely encouraged to raise water use efficiency together with numerous benefits. Farmer learning, as a way of creating awareness about the advantages of water use efficient technologies, was essentially perceived to enlighten smallholder farmers on their benefits. In the irrigation process, there are many instances of water wastage. As a result, farmer learning was initiated to guarantee that the appropriate water use efficient technologies should be used when needed. Therefore, the goal farmer is to intensify awareness about water scarcity by supporting water-saving practices, reducing utility costs, maintaining green spaces, and guaranteeing a system's water supply.

Dinar et al. (2019) argued that increasing water shortage and rainfall erraticism due to climate change and weather variability pose a critical threat to food security, and household welfare and the intensity of these challenges is expected to increase currently and in future. Increasing water use efficiency in irrigated farming has the potential to contribute considerably to hydrological sustainability and to coping with increasing water shortage thereby boosting crop productivity and household incomes. Water-efficient technology adoption has been suggested as a means to increase water application efficiency without having dangerous effects on farmers' incomes (Bopp et al., 2022). The integration of innovation can influence a transformative paradigm shift in water management sustainable development that helps in understanding how water resources management and technology are connected.

Prominence, defined as the extent to which a technology is perceived as being better than the one it succeeds, is another important intervening variable that is also assessed in this research study. It is, therefore, argued that the more a technology or a practice is introduced and is perceived to be comparatively better than the customary practices, then the higher the adoption is potentially likely to be expected (Duvel, 1991, 2004; Rogers, 2003; Salam and

Arifin, 2020). Based on this definition, participating farmers were asked to specify what they considered to be the relevant technology and practice(s) that compared with their old practice to the user-friendly soil water and nutrient monitoring devices.

The acceptance, adoption and use of an innovation may have profound influences on the culture and socio-economic circumstances of smallholder farmers. Technology can improve efficiency, create new farming business opportunities, and enhance quality of life. Table 4.32 presents the research findings. The null hypothesis of equal prominence was therefore rejected as the user-friendly devices were much superior in water use efficiency than the traditional water conservation practices.

Table 4.32

Relationship between Technology Prominence and Suggested Water Use Efficient Practices

Prominence	**Bwanje Valley**		**Khamalathu**		**Mulunga**		**Total**	
	n	%	n	%	n	%	n	%
Low prominence	4	12.9	2	8.3	5	15.6	28	32.2
Medium prominence	24	77.4	14	58.3	12	37.5	33	37.9
High prominence	3	9.7	8	33.3	15	46.9	26	29.9
Total	31	100.0	24	100.0	32	100.0	87	100.0

X^2 = 12.3718; the *p*-value is 0.014791.

The apparent prominence evidently looks to have an influence on the use of the technology introduced in the study areas. As shown in Table 4.32, the majority of respondents (70.1 percent) alleged the technology to have a low or medium prominence relative to old practices of water application. Technology prominence can be described as the level to which a technology is observed as being superior than it displaces. This is an intervening variable that has been assessed. Considering the relationship between perceived prominence and relevance, it is revealed that there is a highly significant correlation ($r = 0.713$, $p = 0.000$). The findings are similar to what Gorfe (2004) found of positive relationship between prominence and use. With this finding, it can be argued that the better a technology is alleged to be rather better than the customary practices, the greater the adoption is expected to be (Duvel, 2001, 2004). Improving water use efficiency aims at decreasing water application within irrigated farming systems while continuing to sustain optimal crop yield rates. Besides, water use efficiency affords a significant number of environmental and socioeconomic advantages. High-level irrigation efficiency is becoming increasingly important because of the prevailing water resources shortages and unprecedented population increase that are driving the intensification of agricultural activities (Kangmennaang et al., 2017).

Participants in the FGD were also asked to provide the perceived benefits and drawbacks of user-friendly soil water and nutrient monitoring tools and how they considered to be important in their irrigated farming decision-making processes. The most important advantages mentioned included more time spent doing other chores, few conflicts arising as a results of water abstraction, good taste and good grain quality. On a five-point scale, participants were requested to indicate the importance of each benefit and drawback in influencing their farmer adoption behaviour and are regarded as positive and negative forces respectively to the adoption.

The perceived benefits and drawbacks of the tools are some characteristics of farmer pinions that can have influences on the adoption and use. The perceived benefits of the devices will be presented first and followed by the perceived drawbacks based on the notion that the adoption and use of the tools are ascribed to the favourable perception about the benefits of the tools. Some of the participants mentioned the benefits as the negative forces that influenced adoption behaviours of farmers. For example, most of the participants mentioned that the user-friendly devices reduced periods of water applications yet farmers realised high crop yields as a highly positive influence that heightened adoption decision. Besides, for those who considered attaining high crop yields with the contemporary practices having no effect and therefore a negative force, there was no acceptance and adoption to use the technology among them. A high significant correlation was therefore above ($r= 0.637$, $p= 0.000$).

Evaluation of the Findings

The increasing popularity of soil water monitoring technologies and their use to improve agricultural productivity and water resources management as a part of food insecurity and poverty interventions has prompted researchers and academia to engage in new inquiries and studies to find user-friendly devices that illiterate people can use (Calicioglu et al., 2019; Foran et al., 2014). Experiential research into the influences of water monitoring technology-enhanced learning which focuses on increasing water use efficiencies and crop yields is currently accessible (Cascio and Montealegre, 2016). Accepting the speedy advances and the increased dependence on technology, the question that would be asked is; “How are new technologies transforming the lives of people, particularly farmers in the wake of climate change and weather variability?”

This section attempts to explain and clarify the progress, direction, and purpose of recent research on the effects of soil water and nutrient monitoring technology on selected SIS in Malawi. We currently live in a global village where there is a higher dependence on technologies of various forms, particularly information and communication technology (Srinivasan, 2018; Dixon, 2009). This form of technology is influencing several sectors and is transforming how businesses are not carried out in the usual manner. It makes and captures the value of doing things differently, how and where people work, and how they interact and communicate with each other. This is how researchers have developed a modern soil moisture detection device called chameleon that is anticipated to advance agricultural production.

Stirzaker et al. (2017) claimed that changing water into food for vulnerable groups on Earth is the best thing one could do.

The chameleon and fullstop wetting front detector are electronic soil sensor tools created by the Commonwealth Scientific Industrial Research Organisation in Australia (Svedberg, 2019). The Chameleon device comprises a series of fairly inexpensive and easy-to-use instruments that are fixed into the soil at different levels between 15 and 60 cm where crop roots dynamically absorb water. This device senses the level of soil moisture content and has 3 colour types of exposure that alert farmers when to apply or not apply water to crops. This technological innovation is about farmer interaction as a way of providing water for better yield and water conservation. These colours are green displaying adequacy of soil moisture content, blue designates medium soil moisture content and red as is the case with this colour code indicates a warning that the soil is dry and there is a need to apply water to satisfy the root zone water requirement.

Equipped with this type of information, farmers can be able to manage their crops more resourcefully, by understanding when to irrigate to avoid stressing the crops and by working out the quantity of water the soil needs. Besides the devices help to avoid nutrient leaching by deciding when the soil profile may be holding too much water, which sometimes may be capitalised on rainfall. The function of a fullstop is to detect whether soil nutrients are being leached out and check salt and nitrate levels availability in the soil. It catches a soil water sample from the root zone and detects how much fertiliser is in the sample noted from colour-changing paper strips.

According to Jones and Olson-Rutz (2011, p. 1), irrigated fields have the highest possibility for leaching, mainly on coarse soil. Thus, if the smallholder farmers use both these devices, they can appreciate how the soil profile is performing regarding water availability status. These devices are being tried at Bwanje Valley, Khamalathu, Mulunga, and Nanzolo. Kasinthula and Cane Growers Association as well as other government research stations. Irrigated farming can be described as the involvement of smallholder farmers that require appropriate information on water resources management, proper infrastructure for water conveyance and delivery, marketing, and other resources to produce better agricultural products (Gomez y Paloma et al., 2020, pp. 99–132). It can be assertively argued that water, not maize flour, is the staff of life. Technology can be used to empower to change their lifestyles. Undeniably, the introduction and application of modern technology in irrigated farming reflect this outcome, as it shall be presented later.

Farmer Learning to Increase Water Use Efficiency

Farmer learning about increasing water use efficiency to enhance crop productivity can help inform solutions to the challenges of food insecurity and household incomes. At a conceptual stage, the self-determination theory suggested by Deci and Ryan (2012) is a most valuable drive. This theory indicates that personal motivation and well-being can be improved when essential needs for independence, ability, and understanding are fulfilled and weakened when they are dissatisfied. Independence can be described as a need to control personal actions, meaning to be an underlying instrument in one's life. Regarding, personal ability is the requirement to experience command to affect personal outcomes within one's surroundings. Whereas, understanding is the necessity to feel that one is interpersonally connected with others and can participate in doing things with others (Becares and Priest, 2015; Greguras and Diefendorff, 2009).

Coovert and Thompson (2013) observed that when technologies are being introduced to the beneficiaries, there are at least four concerns that may influence the acceptability, adoption and utilisation of the technologies. Firstly, concerns economic aspects of the technology and the question, commonly asked is: "Does the new technology have a competitive advantage potential to an institution or a person in terms of his or her life" If indeed it is so, the institution, organisation or a person is more likely to procure and use it for his or her benefit.

The second concern is about the self-efficacy quality of an individual (Bandura, 2012). When a technology is introduced, there are different types of people who are interested and feel competent to use it and are eager to learn how to use it and these can be described as innovators to adopt innovation as they are willing to take risks. However, new technology is likely to experience less anxiety when it is introduced.

The third concern is about easy to use and how genuine it is. Usability concern the interface between the user capacity and technology value to the user (Guerino and Valentim, 2020), and this can be evaluated in terms of efficiency, that is, time to complete a task, effectiveness, error rate, and beneficiary satisfaction.

Lastly, it is crucial to consider and appreciate the role of social issues in the manner in which the new technology is accepted. If a household or family members have reported that their crop harvests and income have improved due to the use of soil water and nutrient monitoring technology, for example, peer pressure increases the possibility of adopting it (Lacombe et al., 2018). Farmer learning is also an emotive learning process that involves rational, sensitivity, and performing to become conscious of the self and others. It is a self-regulating behaviour and taking into account the behaviour of others to make responsible decisions that do not have a peculiar bearing on them.

Participants' Recruitment and Procedures

For this research study a purposive sampling strategy, according to Etikan et al. (2016), was used to facilitate recruiting respondents based on the specified criteria where some farmers were using the devices while others did not but changed their irrigation practices by watching those using them. A control group was used to allow confirmation of that study as a result of the influence of the independent variables rather than irrelevant variables. This control group came from irrigation schemes that had no prior knowledge of the devices and acted as a standard for comparing the findings from those using and not using the devices. The inclusion of control groups in this study was to ensure internal validity. Changes happen over time in terms of the dependent variable and with no control group, it is hard to know if changes have appeared from the treatments. However, it may be possible that the change could be due to some other variables (Crano et al., 2014)

The Challenge to Increase Water Use Efficiency to Boost Crop Yields

Smallholder farmers in Malawi comprise nearly 3.1 million farm families on 6.5 million hectares of land. The country's territorial area is about 11.8 *million hectares* of which *9.4 million* hectares are *land* translating that about 69.1% is used for agriculture under the customary tenure system (MLGRD, 2019). Reports indicated that about 25% of the smallholder farmers cultivate less than 0.5 hectares on average while 55% cultivate less than 1.0 hectares. However, gardens less than two hectares in size can play a very important function in terms of food security (Rammohan et al., 2019). Agriculturally, many parts of Sub-Saharan Africa have poor access to water to grow crops as such irrigated farming makes a sensible venture and a significant priority for empowering smallholder farmers to circumvent household food insecurity and poverty levels that are extensive. Moreover, despite the agricultural dominance, these farmers experience poor nutritional effects and are behind in indices of social and economic progress. Nutritional quality remains pitiable in many emerging nations including Malawi (Aberman et al., 2015)

The impact of climate variability on food security and poverty has been acknowledged as a key issue given the marginal climatic conditions in many parts of Sub-Saharan Africa affecting subsistence livelihoods with restricted resources for acclimatisation. Particularly, the intense reliance on rain-fed agriculture results in agricultural farming systems that are extremely sensitive to rainfall variability as suggested by Cooper et al. (2008). It is known that many communities in sub-Saharan Africa have widespread knowledge of dealing with climatic variability and food security consequences. Subsistence livelihoods have developed several coping approaches to manage weather unpredictability, including drought and sometimes flood years that significantly influence low crop productivity (Roncoli et al., 2001). Shared aims in coping are vividly evident across various regions that comprise a multifarious ordered decision-making process of sacrifice and utilisation of support networks to sustain times of food insecurity.

The approaches that people have used in these times involve responses that include changes to food consumption arrangements where children are firstly considered to eat the available food. Sometimes, a household may grow more famine crops like cassava, and sweet potatoes just to mention but a few (Vaughan et al., 2018). As food insecurity progresses, most rural households consider crucially about survival strategies and they become more worried such that previously acquired domestic resources become increasingly dedicated and likely to back the approaches that become a source of a scapegoat as they sell them to sue the acquired income to buy food.

Irrigated Farming Adaptation to Climate Change in Malawi

It is a fact that climate variability is indeed affecting numerous natural ecosystems and human environments globally. This study applied a solution-oriented diagnostic agenda that was planned along a series of consecutive analytical steps. An initial stage integrated soil water and nutrient monitoring in terms of crop productivity and household income to evaluate the effects of climate change on food security and poverty levels in the selected schemes. To understand whether irrigation was helpful to the farmers, it was decided to use a procedure of naturalistic investigation to pursue an in-depth appreciation of how farmers were learning from the devices available within their natural scheme setting. Its investigation focused on the "why questions" rather than the "what question" concerning social issues. It relied very much on farmers' direct experiences as meaning-making agents in their daily lives (Kristjanson et al., 2017). Multiple systems to acquire narrative information and data for the study included farmer households' socio-economic characteristics and demographic information, factors affecting crop production on the irrigation schemes, irrigation performance and collective action to determine the positivity of farmer learning and attributes or qualities of the irrigated agricultural system.

This research study was considered as consisting of case studies. Why a case study? A case study can be described as an intensive interactive investigation of a person or a group of people, whose purpose is to simplify findings over several parts or components (Ebneyamini and Sadeghi-Moghadam, 2018). Besides, it is practical research that examines a current incident within its real-life context. It deals with the technically unique position in which there are several variables of interest than data arguments and depends on several sources of confirmation. The data collected require coverage through triangulation to validate the findings to be plausible and can be adapted. Stirzaker et al. (2011) stated that adaptive management in agriculture needs the farming system actors vis-à-vis smallholder farmers to learn to do things differently. The emphasis is that learning and adoption of innovation are necessary to switch from dysfunctional irrigated farming practices to an adjustable irrigated farming system. More importantly, adaptive management provides benefits from the preceding development of theoretical propositions to guide data assembly and their analytical procedures through discussion that is beneficial to all participating individuals (Dul and Hak, 2008)

The research was about assessing water productivity and profitability through farmer learning in selected SIS in Malawi. The learning concerned novel devices for monitoring soil water content and soil nutrient conservation. The Comprehensive Africa Agriculture Development Programme indicates one of the vital components for effective water resources management interventions is people-centred learning (CAADP, 2009, p. 24). Since farming deals with older people who participate in learning after realising what they want to accomplish, they attend to acquire what the learning can offer. Thus, based on inventive and hands-on adult learning approaches, this learning involves applied field-based examinations through which farmers learn for themselves what they require. Besides, they learn how to classify, ascertain and recognise how they can address their challenges and problems through inspection, trying and watching different ways of solving their predicaments. Farmer learning is one form of social learning as people are involved. Adult learning is conducted through collective reviewing and sharing findings in subgroups and conducting plenary discussions with others having common issues. By revealing their experiences, learners are encouraged to answer how the learning experience is resolving their family's daily lives and the function the learning activity is playing in supporting in controlling their development and improved well-being (Duveskog, 2013).

The farmers observed, during the survey, that they were pleased with the devices assisted in reducing water application and minimal leaching of soil nutrients thereby promoting efficient and cost-effective irrigated farming. Moreover, some farmers reported that the devices' water usage was reduced by half as water application was extended between irrigation intervals. Instead of irrigating between four and six times a month, water application was done once or twice. A very interesting narrative came from married women who expressed their happiness that they had more time devoted to caring for their children, attending to their social obligations in their villages and participating in off-farm businesses to generate more household income. In this regard, the changes and disparities between men and women smallholder farmers influence how people respond to changes in water resources management. Besides, appreciating how gender plays in irrigated farming helps explain the choices farmers make to grow crops and their different options. Involving both men and women in farmer learning sessions on integrated water resources initiatives, particularly increasing water use efficiency, can increase an irrigation scheme's effectiveness and efficiency (Giordano, Barron, et al., 2019).

A few selected farmers were asked to provide their learning process in managing water resources during scarcity and insufficient rainfall. The main objective of farmer learning is to enhance knowledge based on practical experience, skills, technology and new information. It was found that 85.9 % of farmers in all schemes participated to understand water conservation and that applying too much water is not necessarily a factor in achieving a bumper harvest. An interesting observation was that women narrated their stories based on the hardships that their households experienced when rainfall was not adequate to promote the growth of crops. This point underscores the fact that Malawi's rainfall pattern is seasonal and varies by region. Its distribution is so erratic during the rainy season. For those farmers who have opportunities of having plots on irrigation schemes on important issue is the availability and equitable distribution of water supply. In most cases conflicts emerge because of water thefts during nights. This factor was noted to being solved as those farmers using the monitoring devices have reduced their watering.

It can be observed from Photo 4.3 that crops were planted in plots. During this time the farmer had applied water and the researcher wanted to confirm how he determined to apply water on the plot. The crop stand was good and the farmer expressed satisfaction with the way the crop was growing. This farmer was a participant to understand water conservation and amount of water that should be applied. It is clear that the implication of suitable water measurement has been acknowledged by several other experts before, and that significant efforts have gone into creating comparable, effective and efficient measuring instruments .(Meals & Dressing, 2008).

Photo 4.3: Irrigated Plot at Bwanje Valley Smallholder Irrigation Scheme.

Photo 4.4   Irrigated Maize Plot at Bwanje Valley Smallholder Irrigation Scheme.

Photo 4.5 Water distribution between adjacent farmer’s fields plots one using chameleon on the right-hand side.

Photo 4.6 Farmer's plots after crop harvest.

The above photographs (Photos 4.3 to 4.6) indicate the relevance of using the devices to successfully manage and apply sufficient water to the irrigated plots. Those farmers who were not using the devices but were close or adjacent to those using the devices emulated them. The crop yields were almost similar, however. The differences came about because they were not able to follow in much detail what their peers were doing and some did not regularly attend the scheme meetings because of their opinion that the meetings were for those who were using the devices. After the crop harvests and observing the crop yields, farmers had a clear opinion that the devices played a crucial role in increasing crop yields. Those who imitated their neighbours demanded more information on how to do better next time. In the Scheme Manager's record book at Bwanje Valley Irrigation Scheme, it was noted that 69% of the imitators said that crop yields had increased; 73% indicated that they had reduced water application by almost 48%. Of those who regularly attended meetings, 88% were given appropriate water application advice.

Soil Water and Nutrient Monitoring Devices and Farming Practices

WFD placed at different depths display a light, when blue light is displayed it means the soil is wet, green is moist or red is dry soil. The displayed lights show a picture of soil water status and water content from the top to the bottom within the root zone. Consequently, consecutive readings throughout the season show a colour pattern demonstrating how wet and dry the soil has been. This depicts the depth of water that has reached within the root zone and how well water application or rain percolates the soil. Based on this explanation, information gathered from the field survey revealed that nearly 87% of the farmers in all the visited irrigation schemes, particularly those who had chameleon and waterfront detectors had ample knowledge of the devices developed to measure and their relevance (Table 4.33).

Table 4.33

Farmers' Device Measurement Interpretation

Measurement Characteristics	Percentage (%)
Knowledge of chameleon colours	87
• Green - Adequate water available in the soil profile	88
• Blue - Soil water is wet and crops are not stressed	86
• Red - Danger as soil needed water (dry)	87
Fullstop and Waterfront detectors	
• Know what they measure	83

As noted above, the colour lights signposted the level of soil water availability. For both the illiterate and educated, the information was of importance because it indicates the immediacy of applying water as the red colour lights up not to overstress the crops. Similarly, 83 of the farmers knew what the waterfront detector measured. The device evaluated how soil nitrate was either leached or conserved in the root zone. Nitrogen is essential in making sure plants are healthy as they develop and nutritious to eat after they're harvested.

From the above finding narrative, many farmers on the irrigation schemes had changed their irrigated farming practices. Since this was the first type of survey, an indication is that the farmers did so as a result of shared learning from what others were doing with the soil monitoring devices. Some farmers attributed the lesser application of fertilisers, particularly those using the waterfront detectors that increased water use efficiency attributed to fertilizer conservation in the root zone and nutrient management accomplished. Increasing fertiliser application has cost implications in both time and money as well as soil deterioration. In most irrigated facilities, not adequate compost is applied, Compost is soil amendment activity (Adugna, 2016). If the soil lacks or has less organic material applied, the soil becomes compacted and does not retain water when applied, as a consequence, compost makes a great soil amendment matter (Bell et al., 2003). To increase the scheme's efficiency as well as its performance farmers' participation in the management is a must as decisions and ideas given to them may have a significant effect on the operation and the modernisation process of the water supply systems to convince the system sustainability.

The soil fertility status of Sub-Saharan Africa generally and Malawi particularly is generally because of continuous nutrient mining and inadequate organic and/or inorganic resupply. Per se, crop yields have declined and high levels of food insecurity and poverty continue to be observed. Soil health offers the foundation for increased crop productivity and profitability of smallholder irrigated farming systems as well as food security and the enhancement of livelihoods and poverty alleviation (Das et al., 2022). Hence, crop nutrient conservation in the soil root zone needs to be spearheaded so that there is an effective intervention for rural development through investments in the smallholder irrigation sector particularly in stopping the leaching of nutrients.

Faurès et al. (2010) argued that in many areas, farmers work with infertile soils and apply too little fertilisers. They are unable to harvest bumper yields to deliver to markets promptly. The issue of declining soil fertility in irrigation facilities in Malawi has been a significant concern lately that is leading to huge dependence on chemical fertilisers to maintain crop productivity, frequently aggravated by poor water resources management practices that result in nutrient leaching. On the other hand, chemical fertiliser misuse can result into soil acidification and soil crust that can contribute to changing soil pH and even leading to the greenhouse gases release into the atmosphere. In this vein, the farmers were asked whether they use fertilisers to boost crop yields. It was, therefore, found out that more than 75 percent of the farmers use fertilisers in the selected schemes. In the year 2021, 92.5 percent of farmers from Bwanje Valley Irrigation Scheme bought and applied fertilisers, 80 percent from Mulunga and 78.1 percent from Khamalathu. Table 4.34 indicates that the majority of farmers from the selected schemes bought fertilisers and other farm inputs.

Table 4.34

Farmer Responses to Fertiliser Use and Input Market

Reasons for Use, Place and Farmer Perceptions	**Bwanje Valley 40 (%)**	**Khamalathu 32 (%)**	**Mulunga 45(%)**
Did you buy any fertilizer or farm chemicals?			
Yes	37 (92.5)	25 (78.1)	36 (80.0)
If yes, from where did you buy it?			
Retail business	24 (60.0)	15 (46.9)	25 (55.6)
Nearest local outlet	21 (52.5)	17 (53.1)	20 (44.4)
Are there any dealers that offer cheaper prices?			
Yes	8 (20.0)	9 (28.1)	14 (31.1)
No	28 (70.0)	18 (56.3)	25 (55.6)
Not aware	9 (22.5)	5 (15.6)	6 (13.3)
What factors influenced fertiliser prices?			
High transport costs	16 (40.0)	12 (37.5)	19 (42.2)
Devaluation	11 (27.5)	5 (15.6)	7 (15.6)
Lack of time	8 (20.0)	6 (18.8)	10 (22.2)
Could not afford to purchase in bulk	10 (20.0)	9 (28.1)	9 (20.0)

Source: Researcher's data, 2021

The research survey also looked at the farmers' field position on the landscape (Table 4.25). Three positions were decided before the survey activity. When assessing the relevance of location on the irrigation scheme, the head locations had less yield (2.4 tonnes per hectare) compared to the middle location (2.7 tonnes per hectare). Whilst the tail end had the highest yields (3.1 tonnes per hectare). It has to be noted that when irrigating the tail is the first to be irrigated then the middle lastly the head. This is to avoid excessive water application if the head is to be irrigated. At the Bwanje Valley Smallholder Irrigation Scheme, twenty-one respondents explained that with the introduction of user-friendly soil water and nutrient monitoring devices, there is adequate water for farmers to apply on their plots. An increase in crop yield due to water use can be attributed to intentional as farmers depended on the colour of the devices displayed. During dry season irrigation, conflicts were a norm as those located at the top used to abstract more water than the other farmers lower from them. As water becomes scarcer these farmers take advantage of location since water is distributed from the top to down due to gravity. Smallholder irrigated farming system is largely based on using open canals as a water source moved by gravity.

Position of Farmers' Field Plot on the Scheme

The strategy of smallholder farmers at the tail end of a canal is to use the water carefully and occasionally grow lucrative crops. It was observed during this research that these schemes abstracted 2.33, 1.97 and 1.68 l/s/ha by Bwanje Valley, Mulunga and Khamalathu irrigation schemes, respectively. Although these findings reveal that the farmers in the schemes understand productivity of water to mean efficient water use, however their primary focus is on crop yields. Largely, this understanding appears to be comparable to the stakeholders' perceptions of water productivity exclusively with IWMI's concept of crop per drop.

Frequently, farmers whose plots are at the head of an irrigation canal, tend to get more water and the crop yields are more than those below them. This can be claimed that there are high opportunities to access water and luring those farmers to use water carelessly at the expense of those located downstream and crops at the tail end are mostly affected by water stress. This has been the norm for conflicts, however, with the introduction of soil water and nutrient monitoring devices this is not the case. The farmers located at the tail end of the irrigation scheme had significantly higher yields than those in the head and mid locations. The difference between the lowest and highest yield by depending only on the irrigation scheduling was 0.7 tonnes per hectare, an increase of 29%. Whereas the smallest difference obtained depending on the position in the irrigation scheme was 0.5 tonnes per hectare, an increase of nearly 7% (Table 4.35).

Table 4.35

Maize Yield against Position on the Irrigation Scheme Landscape (Bwanje Valley Scheme)

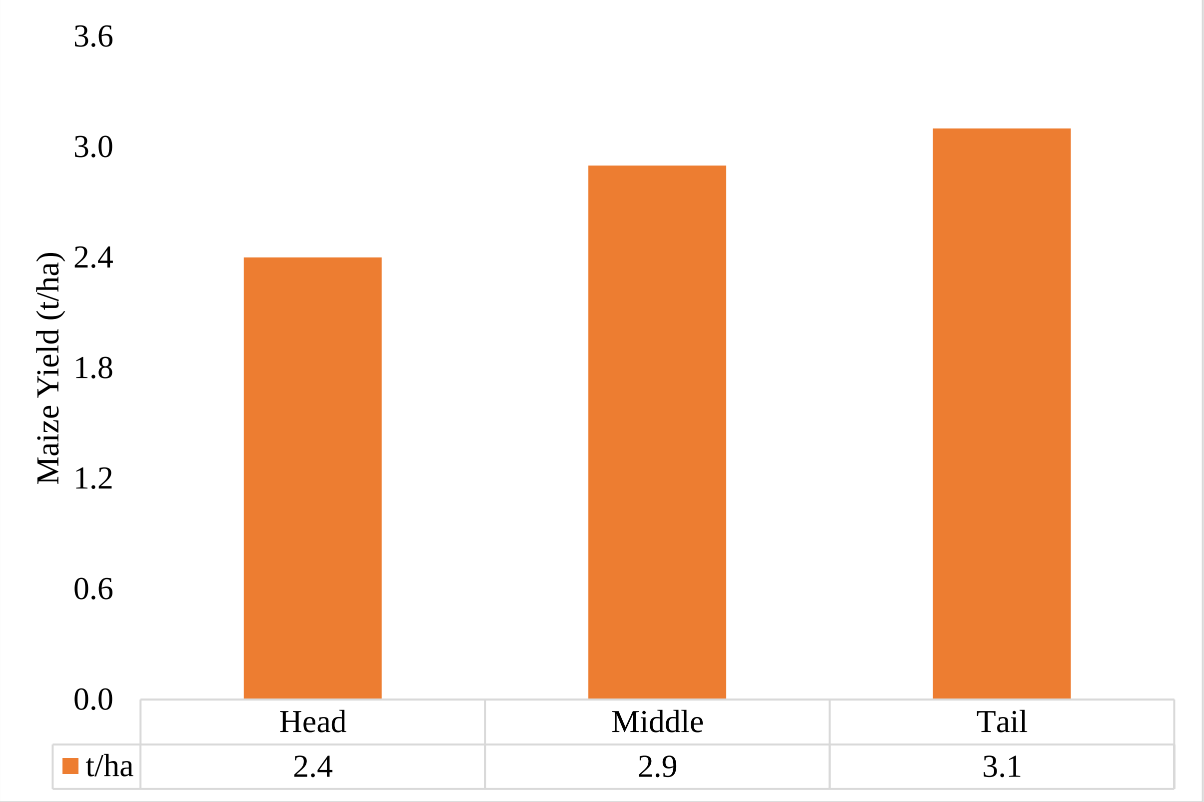
Position	Mean Yield (t/ha)	Confidence interval
Head	2.4^{a}	$(1.3 \leq \mu \leq 3.5)$
Middle	2.9^{a}	$(1.6 \leq \mu \leq 4.2)$
tail	3.1^{b}	$(1.4 \leq \mu \leq 4.5)$

The different superscript indicates significant differences at $p < 0.05$.

Presenting this finding graphically, Figure 4.21 shows the yields harvested from different positions on the scheme's landscape. The tail end had the highest crop yields compared to the other positions. Figure 4.21 shows a distinctive example of low crop yield at the head compared to high crop yield at the tail end of an irrigation canal. Even though at the head of a canal, access to irrigation water was high enticing farmers to abstract water this situation was avoided due to soil water content. Except in some situations where some farmers deliberate ignore the set water delivery schedules, they tend to abstract water unnecessarily. Although technology alone does not regulate sustainability it can have a key influence, particularly on water application and conservation requirements. Nevertheless, at the tail end of a canal the farmers strategy is to use water carefully as crops at the tail end are mostly affected by water stress causing a reduction in yield.

Figure 4.21

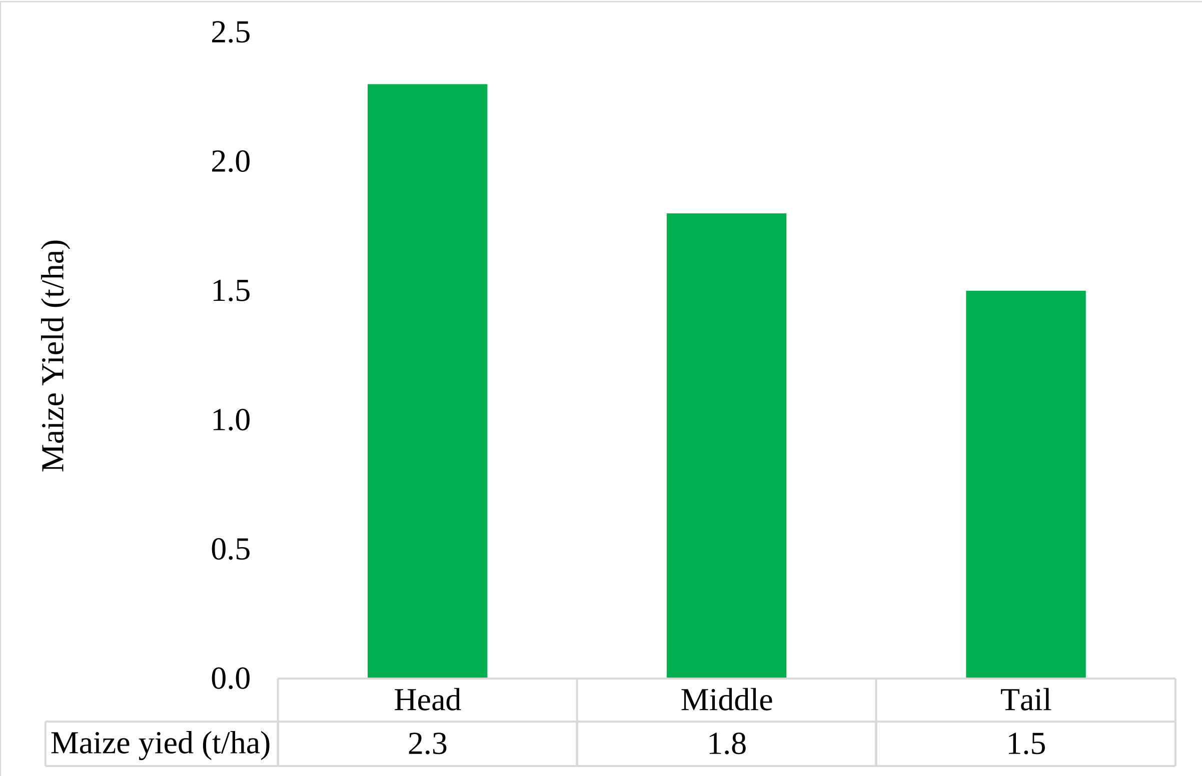
Maize productivity based on plot location at Bwanje Valley Irrigation Scheme



Differences in water supply and their influence on crop production are usually linked to the location on the scheme's landscape whether at the head or tail-end. In most cases, filed plots located at tail-ends are ordinarily considered to be at an extremely disadvantage because farmers at the head-end breach canals. Essentially, where there are experiences of water shortage this is a common incidence as they come during night time to apply water on their plots and this brings conflicts (Bijani et al., 2020). Currently, farmers using the devices no longer abstract excess water as they are informed by the devices when and how much water to apply. Commonly, for farmers whose plots are at the head of an irrigation canal, access to abstract water is high enticing farmers to use more water and eventually leach out soil nutrients something that farmers are ignorant of. The user-friendly tools have clearly shown the importance of efficient water use.

Figure 4.22

Maize productivity regarding the location of the plot (head, middle, tail) at Tiphunzire Smallholder Irrigation Scheme



Frequently farmers' plots located at the irrigation canal head tend to get more yield than those at the tail end (Figure 4.21). This finding is the opposite of what was assessed at Bwanje Valley Irrigation scheme. This is an irrigation scheme that did not participate in the project of using soil water and nutrient monitoring tools. Due to farmers' illegal water abstraction, crops at the tail end are mostly affected by water shortage contributing to crop yield reduction. This demonstrates the fact that most farmers at the head of the canal apply more water than those rat the tail end. This explains the farmers' model of more access to water equates to obtaining a high crop productivity and not achieving high crop yields and Tiphunzire irrigation scheme displays device relevance.

Table 4.36

Maize Productivity against Irrigation Scheduling

Irrigation scheduling	Yield (t/ha)	Confidence interval
Control	1.9[a]	$(0.7 \leq \mu \leq 3.1)$
Imitators	3.3[bc]	$(1.3 \leq \mu \leq 5.3)$
Chameleon	3.6[c]	$(1.4 \leq \mu \leq 5.8)$

The different superscript indicates significant differences at $p < 0.05$.

The average maize yields based on waterfront detectors and Chameleon use indicated significantly higher yields than the control. According to the principles of soil water infiltration, if the soil is not moist before water is applied the wetting front will not infiltrate deeply as dry soil will absorb most of the water. Conversely, if the soil is fairly wet before water application, the soil cannot store much more water thereby allowing the wetting front to infiltrate deeply and affecting crop yield (Figure 4.19). These indicators suggest a strong positive relationship between maize yield and the use of the devices in terms of irrigation scheduling. The meaning of irrigation scheduling is that it allows farmers to apply the precise water quantity to achieve the bumper crop yield goal and this encourages increasing water use efficiency. However, under SIS, a critical component is the accurate measurement of water volume application or the depth of water to be applied.

Outcomes of FGDs

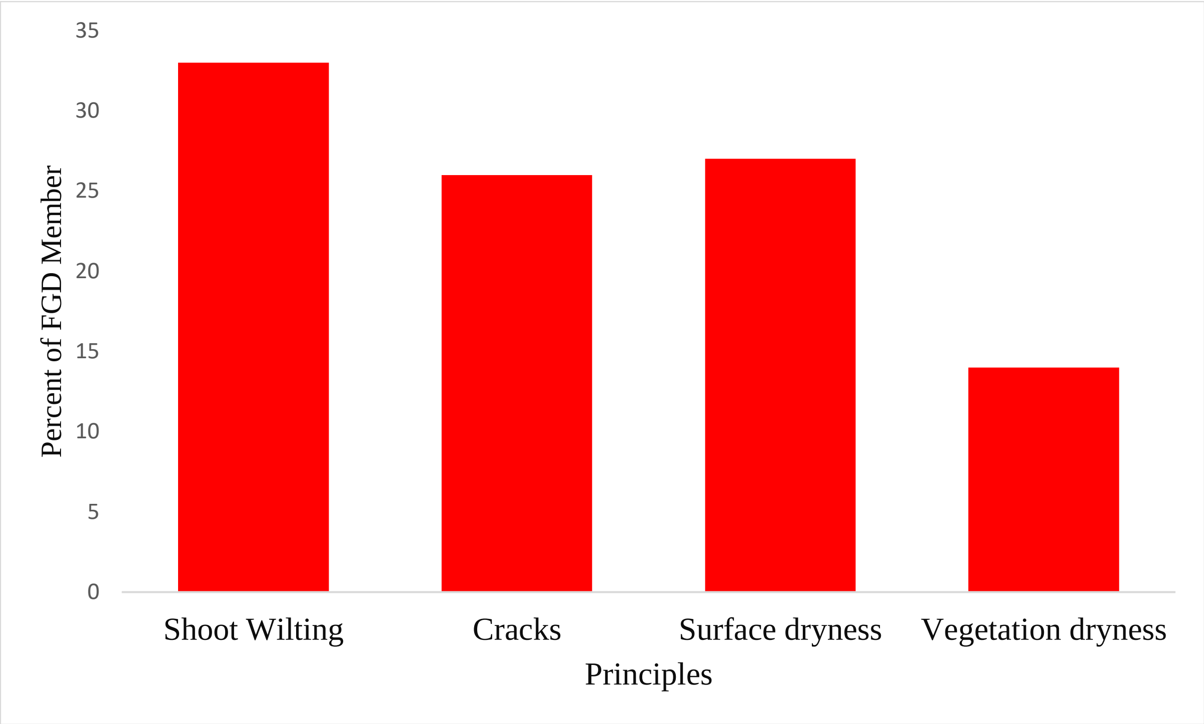
The opinions of smallholder farmers' concerning water productivity concept in a country like Malawi are relevant. The findings from the questionnaire survey and FGDs revealed that farmers use four principles to establish when to irrigate. With the first standard, farmers observe leaf and shoot wilting signs, with the second standard they perceive degrees of soil waterlessness showing, cracks on soil surface and the third group indicated plant colour and curling of the leaves. While some participants said that squeezing soil together and shake it out, if the soil still grips together with a few crumbs falling out, the soil is moist. However, if it holds its shape and can be moulded into something, it is too wet.

It was, nevertheless, found that the principles of determining soil wetlessness are important, where the majority of farmers use leaf and shoot wilting (33%), the second group use soil cracks 26%, third wilting signs (27%) and soil squeezing (14%) as a sign of when to irrigate. The perceptions were narrated by farmers during the FGDs. It is apparent that there is a very robust connection between farmers' speculative appreciation of water productivity by taking their actions to attain higher water productivity. For instance, a simple demonstration proved that farmers' rainfall classification of a season agreed squarely with the real situation. Consequently, indigenous environmental knowledge plays an important role in natural resource management and cannot completely be ruled out. Besides it can significantly augment climate policies and actions (Mensah, 2019). It is apparent, therefore, that there is a solid link between the farmers understanding and water application with their actions to achieve crop productivity and profitability. In the study areas, no technical irrigation scheduling has been practiced before until recently.

Farmers have been scheduling their irrigation merely by observing soil moisture and crop conditions. These determined when the next irrigation would be to apply water by observing when the surface soil starts cracking and plants start wilting during unclouded days. These came out more vividly when opinion and local leadership were asked to narrate the common methods farmers use to determine when to use. However, they were quick to say that even though these methods are commonly used, they do not determine the quantity of water to apply. WFD brought new knowledge to the farmers, one leader observed that, the devices helped to imagine and understand what is taking place in the root zone regarding water absorption.

Figure 4.23

Principles used by Farmers to Decide When to Irrigate



One of the key reasons why focus group discussion are used in qualitative research studies is that they produce valuable information that can be used to ascertain and detect what should be considered by the policy-makers and experts to advise the farmers on what should be done (Galindo-Gonzalez and Israel, 2017; Gundumogula, 2020). This is based on what worked, what did not, and what their technical hitches were. The latter supports identifying methods and approaches to improve what is being promoted to change the circumstances that are being faced by the people vis-à-vis farmers concerned. FGDs, furthermore, facilitate the collection of success stories and the salient information that characterises a human face on responsibility accounts. Thus, such accounts can be essential in interactive processes with stakeholders regarding how the learning programmes instituted may have helped both the smallholder farmers and extension clientele (Neef and Neubert, 2011).

Knowledge and awareness of irrigated farming methods extension, and farmer learning as well as the reactions to water resources management through the utilisation of soil water and nutrient tools in the selected irrigation schemes, were explored, using focus groups. The relevance of these tools was identified and resulted in the creation of weekly meetings so that those who did not have the opportunity to see what the tools were showing in lessening water application could hear in real-time and from their fellow farmers. This finding concurs with the discourse in the participatory approaches in agricultural research that essentially emphasises how to blend various forms strategies and intensities of participation with quality farming science that moves beyond the simple farmer-first ideologies.

Smallholder farmers who are adults learn through experiences. Experiential learning is the process that encourages learning by putting hands on what is being promoted to be adopted. By engaging smallholder farmers in hands-on experiences and thinking, they are in a better situation to connect theories and knowledge they perhaps learned in the classroom setting to real-world situations. Using this setting for assessing the agricultural extension situation is the novelty offered by this research study as the experiential learning theory was applied in water resources management to enhance household crop productivity and profitability.

Providing power to smallholder farmers repositions the locus of involvement towards individual farmers, daring that the system change is possible through its weakest actors at the individual scale. Smallholder farmers particularly women are comparatively helpless, frequently have unjustifiable land tenure are usually dependent on other more powerful people for trade accessibility, and do not have the economic power to respond to ecological, shared, and technological variability (Fatch et al., 2021). The research findings suggest that food insecurity may not be more severe for female-headed households than for male-headed households. In terms of the key factors contributing to food security, the use of soil water and nutrient monitoring devices is the game changer because there was not much difference between the male and female farmers that used these tools. The findings, further, reveal that food-secure households are largely those that have had increased crop yields due to device use, but the landholding sizes were the same size and there was no difference

This study was guided by five hypotheses as per specific questions and objectives. The first hypothesis looked at the application of better farming practices based on farmer learning to affect food security unless there are unnoticed or falsely observed conditions that are key bases of neighbours' outcomes. This hypothesis was not rejected as those farmers who participated in learning and imitated what their peers were doing increased their crop harvests.

The second hypothesis that there is no significant relationship between socio-economic characteristics and farmer learning to improve water resources management and increase water use efficiency was rejected. This was based on the fact that some of the poor-resource farmers were not part of those using the soil water and nutrient monitoring devices.

The third hypothesis about farmer learning is related to overall household food security and income as social benefits enhance and boost the farmers' interest in participating in learning. This hypothesis was overwhelmingly supported based on the reports respondents said. Some farmers were able to purchase motorcycles, and others indicated they built new houses, roofed with iron sheets.

The fourth hypothesis that farmer learning under various institutional arrangements does not influence water resources management and water use efficiency was accepted to be true. On the irrigation schemes, various institutions were responsible for planning water delivery (water users association) and cooperatives.

These institutions helped in resolving conflicts if farmers fought over distribution. While cooperatives made sure to find lucrative markets for their crops. Lastly, the hypothesis is that farmer learning is expected to significantly improve water resources management and increase water use efficiency. This was very obvious as many farmers reduced water use and harvested more crops. It was recognised also that inefficiency in production was significantly influenced by the shortage of water and inadequacy of fertiliser application.

Summary

A summary of how a farmer participates to use soil water and nutrient monitoring devices in SIS emphasises the arguments provided in the paragraph below.

Farmers understand soil health as they learn how to evaluate and manage soil fertility and health that include soil texture and water retention. Appropriate soil management guarantees that crops can prosper by decreasing the need for disproportionate irrigation and enhancing water usage. Farmers to increase efficient water use through learning as this helps how to apply water effectively and the required time. This includes when water is required by different crops, to evade water wastage and stressing crops. As a very notable issue, farmers introduced to monitoring tools are helped in maintaining soil conditions and water usage and support them to make data-driven decisions as to when and how much water to apply on their plots thereby improving efficiency and increasing crop yields. The emphasis in all these activities is on sustainable irrigated farming practices, such as efficient irrigation and soil conservation methods that make sure long-term soil fertility and water availability.

Kelfas et al. (2024) observed that farmers in SIS have learnt to integrate knowledge of soil status, water management, and current monitoring tools to improve productivity, reduce resource wastage, support sustainable farming practices and ultimately profitability. The implications of the research study after evaluating the hypotheses are presented in Table 4.37. Nonetheless, most of the respondents were concerned with access to water and not water use efficiency mainly by the control group. Their view was that if there is any increase in crop productivity it is attributed to water use rather than reducing water application. For example, where water is in short supply, farmers tend to use the available water sparingly by irrigating high-value crops like vegetables. The variation in appreciating water resources utilisation and the insistence of farmers not using the tools to monitor usage is indeed very valuable.

Table 4.37

Hypotheses Test

Hypothesis	**Description**	Corroboration
H1	Application of better farming practices based on farmer learning will affect food security unless there are unnoticed or falsely observed conditions that are key bases of neighbours' outcomes.	Yes
H2	There is no significant relationship between socioeconomic characteristics and farmer learning to improve water resources management and increase water use efficiency.	No
H3	Farmer learning is related to overall household food security and income as social benefits that enhance and boost the farmers' interest in participating in learning	Yes
H4	Farmer learning under various institutional arrangements does not influence water resources management and water use efficiency.	Yes
H5	Farmer learning is expected to significantly improve water resources management and increase water use efficiency	Yes

CHAPTER 5: IMPLICATIONS, RECOMMENDATIONS, AND CONCLUSIONS

Introduction

The prevailing, climate change and variability are among the most debated and discussed topics across the globe, exclusively in countries where rain-fed agriculture determines the means of a significant number of smallholder farmers' livelihood. Climate change and variability promoted and exacerbated increased erratic and low rainfall, predominantly in areas where food insecurity is very high and significantly affects vulnerable groups. Moreover, they increase the threat of famine in many areas worldwide as it concerns all four constituents of food security, namely: availability, accessibility, utilisation and stability.

This current research was considered to assess water productivity and profitability through farmers learning about the new technologies that enhance crop productivity and increase water use efficiency in selected SIS in Malawi. The soil water field capacity concept sometimes provides misleading conduct in the manner in which water application is done (Evett et al., 2019; Datta et al., 2017). Most water monitoring devices are designed based on this concept, however. Farmers, in SIS, who intend to achieve food security and reduce their poverty levels need to learn and overcome water application abuse and increase water use efficiency. Access to training, appropriate technologies and a conducive environment may make a difference in whether or not they can successfully participate, appreciate and increase water use effectively. Besides, observing and emulating what others are doing on the same irrigation scheme is one way of shared learning.

The requirement to reduce poverty, enhance food insecurity, improve resilience to climate variability (Vitsitsi, 2019) and increase economic growth (Pittock et al., 2018), most African countries and donors alike are devoting billions of financial resources to new irrigation investments. Nevertheless, smallholder farmers' perception is a vital element in irrigation development. Development can mean numerous things to people. It is generally recognised that human development concerns expanding the choices available to manner of people to live valuable lives and this is also relevant with irrigated farming. Accordingly, farmers must be at the centre of irrigated farming development, both as beneficiaries and participants. The People-Centred Approach is a developmental idea that can support irrigation development in sub-Saharan Africa generally and Malawi particularly (Nagan, 2016; Bleidorn et al., 2013; Bwalya et al., 2009; CAADP, 2009).

Research Study Implications

Effective water resources management on SIS is a vital prerequisite for sustainable crop production to improve food security and reduce poverty. Yet, learning approaches that enhance smallholder farmers' knowledge, opinions, and attempts to deal with water shortage by encouraging farmer learning and technical innovations are rarely carried out (Aguilar et al., 2022). Water scarcity due to climate change currently poses one of the most noticeable threats to smallholder farmers' livelihood and welfare. According to Rockström (2000), water shortage disruption is one of the biggest risks that smallholder farmers experience globally.

Water availability deserves exceptional attention in terms of resilience as it is an important factor in every aspect of farming and other systems of major productivity. Conversely, water's uneven distribution and accessibility contribute negatively to some agricultural areas that are more exposed to the likely increase in drought frequency and magnitude (Meza et al., 2021). Above all, among smallholder farmers, it is necessary to better understand some of the resources that can improve and augment their flexibility to overcome water shortages. Besides, the findings revealed that smallholder farmers' knowledge and perceptions about water resources management and increased water use efficiency changed visibly.

Farmers' practices in the management of weed infestation improved as they realised that weeds were competing for water (Isaac et al., 2013). Learning about the causes of food insecurity stimulated the recognition of locally relevant diffusion channels and the feasibility of a range of recommended water resources management approaches. Furthermore, smallholder farmers accepted their interdependency, responsibility, and function to liaise to reduce water mismanagement in their irrigation schemes. Farmers learning aimed at improving current knowledge, opinions, and farming practices to deal with water resources management combined with experiential and shared learning approaches can change local farmers' knowledge and provide a mindset change springboard (Phiri, 2011).

Since this research study was conducted among the smallholder farmers who ranged from user, imitators and ignorant farmers, those who did not know the existences of the device, the findings were inclusive. The study therefore sheds more light on the value of farmer learning, relevant institutional interventions for developing a farmer network to spread knowledge and ideas among the smallholder farmers. It is well acknowledged that farmers depend more on individual interactions with their peers, acquaintances, agricultural professionals, and extension delivery services for new technology, ideas, knowledge, etc., than the prescribed conduits of information sharing. Well-directed training for the smallholder farmers can improve and increase agricultural productivity, in turn, will improve the living standards of the smallholder farmers themselves. Lastly, the research study used an empirical analysis through use of primary data and it has been proven that local institutions are significant and imperative for developing social links through interactive exchange of ideas is important.

The Contrast between Water Use before and After Irrigation Tool

The initial findings concerning irrigated farming practices that existed before the introduction of the soil water and nutrient monitoring devices many farmers in the irrigation schemes have expressed their concern that the devices should be readily available and inexpensive. The first hypothesis that the application of better farming practices based on farmer learning will affect food security unless there are unnoticed or falsely observed conditions that are key bases of neighbours' outcomes has been narratively supported by the farmers indicating that smallholder farmers were satisfied that farmer learning has a statistically significant and positive effect on crop yields. This finding implies that, in the absence of quantitative, when farmers objectively applied water according to what the colours lighted on the devices, their perceptions could be deemed as a valid substitute. On the other hand, there was no statistically significant evidence found to support the second hypothesis that there is no relationship between socioeconomic characteristics and farmer learning to improve water resources management and increase water use efficiency. This suggests that farmers' perceptions of socio-economic characteristics are not significant for irrigated gross household incomes when other more pertinent social, physical, and financial factors are controlled for. This implication also highlights the fact that crop productivity on irrigated schemes does not necessarily translate into improved irrigation farm income unless farmers have adequate information and knowledge on water application adaptation. Soil water devices are the game changer. Doing this, as usual, is archaic and old-fashioned.

The second hypothesis investigated whether there is no relationship between socio-economic characteristics and farmer learning to improve water resources management and increase water use efficiency. The research findings revealed that there were substantial inefficiencies in water application on the schemes as there was no tool used to measure or gauge how much was available within the root zone. This finding is consistent with a recent what Bravo-Ureta et al. (2007) claimed to have been happening among smallholder farmers. In most developing countries surface irrigation is much more popular than drip and sprinkler irrigation systems possibly because of high investment costs (Burney et al., 2013). Besides, the poor performance of the surface irrigation schemes, extensive inefficiencies are expected. This statement is backed by the results that exhibited scale inefficiencies to be significant, less than 60% on average, with almost all irrigation schemes functioning at escalating returns to scale.

The implication of this is that most farmers' plots should be larger than they currently are (0.09 hectares) to produce bumper yields. In this case, the devices introduced in the schemes could make a tremendous difference under the present water application conditions. Whilst this is the case, Binam et al. (2003) large scale inefficiencies by farmers in Ivory Coast for coffee growing. Conversely, in Eastern Ethiopia Haji (2006) observed that in smallholder farmers practising traditional irrigated farming methods, the scale inefficiencies were practically missing. It can further be argued that the dearth of requisite tools and information by smallholder farmers fails to reach overall technical efficiency levels in terms of water use efficiency. The steady introduction of soil water and nutrient monitoring devices to SIS in the Southern African Region can perhaps prompt more efficient water use that may enhance crop productivity (Izzi et al., 2021; Mabhaudhi et al., 2019).

Because of the above, a fascinating implication due to the introduction of these devices, there appears to be a sizeable scope for decreasing water usage, even with the technology presence on the schemes as many of the farmers are imitating what their peers are doing. The result is that if water use efficiency increases, it may be likely that the water users association responsible for water delivery to farmers' plots may reallocate the unused water to other areas of water demands without risking production or the role smallholder irrigation might play for household food security, income as well national economic development (Horbulyk and Balasubramanya, 2018). So, the hypothesis of no significant relationship between socio-economic characteristics and farmer learning to improve water resources management and increase water use efficiency is untenable. This means that certain factors may either promote or hinder participation in farmer learning programmes.

The study also examined household food security and income related to prevailing irrigated farming practices and household characteristics in the selected SIS. A proposition was formulated to investigate whether farmer learning can be related to overall household food security and income. Incidentally, ending famine and poverty reduction are the two most important goals for a sustainable future globally. Food security and poverty are relentless challenges for rural communities in Malawi (Hajdu et al., 2009). Frequent droughts considerably affect the agriculture sector, threatening the livelihoods of many smallholder farmers, who comprise 80% of Malawi's population. However, 38% of the population lives below the poverty line, and nearly 50% of children are stunted.

The third hypothesis concerned food security and household income to be linked to learning with a view to increase water use efficiency. Crops as well as livestock need water to grow and live. The findings of this study showed that the technology users harvested more crop yields. For the control group had ideas that crops require large quantities of water for irrigation and more often conflicts ensued. This was contrary to users and imitators as they indicated that they had more time to do other domestic tasks. They only went to their plots when the devices showed red colour mainly in extreme cases as water stress rises fast after this point (Stirzaker and Driver 2024). Farmer learning has demonstrated that it can improve food security and household revenue through enhancing crop productivity, assisting farmers accept and adopt new technologies, and improving water resources management techniques. This research has found these to be true, besides, water is integral to household and individual economic productivity.

The fourth hypothesis inspected the contribution of institutional arrangements whether it does or does not influence water resources management and water use efficiency considering farmer learning on irrigation schemes. It has been noted by both researchers and academia that the institutional structure and arrangements of the agricultural sector are a difficult socioeconomic system that comprises organisational, legal, economic, honest and ethical components. The development of society in the process of market transformation leads to a change in the role of individual institutions and their importance. From the SIS in Malawi, the institutional perspective appears to be of importance. What makes the institutions regarded as such is the water use efficiency aspect whereby if an improvement can be made there could be significant differences in house food security and incomes.

The findings after determining hypothesis four showed that water users' associations were available on respective schemes that supported and helped in water delivery according to the bye-laws formulated. While conflicts ensued, it was the water users' association that resolved and pacified the situation. Cooperatives also were helpful in terms of finding lucrative markets for their crops grown on the schemes. The implication is that if the irrigation bye-laws have specified clauses on conflicts that arise to be managed by the association as well as the scheme management that may lead to effective irrigation water management.

The last hypothesis examined that farmer learning can significantly improve water resources management and increase water use efficiency. This proposition was thoroughly examined by interrogating farmers on how they could improve crop productivity and increase water use efficiency. Particularly increasing water use efficiency is of major concern when drought occurrences are so frequent and pose huge problems in limiting food production, hence causing food shortages. Effective water resources management for crop production when water resources are in short supply requires efficient methods. Increasing water use efficiency and planting drought-tolerant crops may be one way of achieving efficient and effective water use. Since most smallholder farmers are unaware of when and how much water to apply, there is a need for them to be trained to conserve water using novel devices that they can use. From the survey findings, it has been noted that farmers after training reduce water application significantly.

The Implication of Soil Water and Nutrient Device Application

Traditional water application approaches to irrigated farming development have emphasised technically engineered technologies to measure soil water content leaving behind the farmers who are the ultimate beneficiaries of managing water resources. To enhance the performance of irrigation schemes, it is important to increase water use efficiency and introduce ease-to-use water application technologies. Since many SIS are stuck in the undesirable fate of infrastructure ruin, unprofitable farming and lack of investment, realigning these farming systems into productive, lucrative and efficiently sustainable irrigation schemes needs a mindset change.

It must be recognised that water use efficiency can be described on several scales from the leaf to the field to allow researchers to study and examine how water is used at different scales within an ecosystem and importantly depending on the area of focus. Water use efficiency can simply be defined as the ratio of yield to the water used during crop growth according to Waraich et al. (2008, 2011). The ratio of crop yield to transpiration can be described as transpiration efficiency. The transpiration efficiency defined as the biomass amount produced per unit of water transpired has been advocated to be a trait of interest to enhance crop productivity in water scarcity areas, particularly where crops rely on stored soil water content and not where crops are hydroponically produced. Hydroponics is the method of growing plants using a water-based nutrient solution instead of soil.

Water use efficiency offers a simple way of evaluating whether crop productivity is constrained by water supply or some other factors. A better appreciation of crop productivity depends on the effects of water use efficiency and may in a way provide researchers with openings to recognise and identify suitable agricultural farming practices to increase water use efficiency and thereby significantly improve crop yields (Giller et al., 2021). While food insecurity is a result of water shortage, in Malawi, there are ample water resources with a lake that has freshwater resources and irrigation started way back in the 1940s Gwiyani-Nkhoma (2013), one would encourage SIS should be transformed and revitalised.

The transformation issue should be in terms of transfer of ownership to farmers and the revitalization, on the other hand, is the investment increment in renovating scheme infrastructure and farming practices, along with better governance on SIS. Enhancing crop water use efficiency will continue to be discussed due to the increased demand for grain production. Better crop yields per water drop are one of the most critical challenges in water-limited areas of the world (Hatfield and Dold, 2019). There is an increasing need for smallholder farmers to be supported with appropriate technologies and to be trained in irrigated farming practices that can sustainably improve crop productivity and resilience, while at the same time reducing greenhouse gas emissions into the environment whenever and wherever conceivable.

Indeed, technologies such as chameleon and WFD, integrated with an application of organic/inorganic sources of nutrients, are claimed to be promising climate-smart farming practices (Abberton, et al., 2021). If these can be supported by governments and the donor fraternity, could widely be used by smallholder farmers to improve household food insecurity and secure decent farmers' livelihoods while contributing to ecosystem conservation services. Moreover, Malawi is characterized by high demographic pressure in 2018 the population was nearly 17.6 million on land has a total area of 118,480 km² (NSO, 2019). The political context is very stable with no wars since independence in 1964. However, there is forceful radicalism in terms of natural resource use and vulnerability to climate change effects, which is accelerating environmental and natural resource degradation. Despite these limitations, there are prospects to scale climate-smart answers for increased food security and resilience among the rural population.

Due to recent weather vagaries like Cyclone Idai and Elisabeth, the country has natural comparative advantages for agricultural-livestock integration, climate-resilient, drought-tolerant crop varieties as well as high-value tree species, for instance, Mulanje Cedar (Hunter et al., 2020). Murray et al. (2016) indicated that the International Fund for Agricultural Development has been raising a flagship programme portfolio of activities whose purpose is to convey climate and environmental finance to smallholder farmers as an adaptation strategy to design projects that integrate issues of climate variability effects on smallholder farmers. Because of the circumstances that Malawi is facing the International Fund for Agricultural Development designated a climate risk analysis to evaluate the latent impacts of climate change on agricultural crops. But the full climate risk analytical report gave an analysis of, among others, the current and future climate characteristics, possible changes in crop suitability under variable climate scenarios; and the likely uncertainties and socio-economic influences associated with climate variability, as well as probable adaptation alternatives and prospects for increasing climate resilience. Nevertheless, the report did not indicate appropriate tools that farmers could use to assess soil water content. This was a missing relevant point.

Investment in user-friendly technologies like the Chameleon and Water Front Detectors is very relevant in investing in smallholder farmers to learn and establish allied value chain networks is necessary and important. It is currently impractical to consider SIS if farmers do not learn modern methods of farming and remain reliant on the government or private sector for support. Several initiatives are needed to transform these farming systems into productive, lucrative and sustainable schemes. The study, therefore, recommends that further studies are needed to explain and confirm some of the findings given in the thesis.

Climate Risk Management through Participatory Weather Data Collection

Smallholder farmers in rain-fed and drought-prone areas most often struggle with how best to use scarce water resources. In the wake of climate variability, there is an urgent need to increase water use efficiency for sustainable farmers' livelihoods and national economic development. It has been observed that soil water and nutrient monitoring devices are advancing the livelihoods of smallholder communities in the country by decreasing their time to irrigate crops effectively. This statement has been taken from some of the respondents the researcher interacted with during the field survey. Generally, the findings show that farmers have seen between a 45 and 50% reduction in the time they normally spend to irrigate crops. This extra time allowed the extra effort to improve their plot management like weeding which led to better crop stand and increased household food security and income. It makes sense when smallholder farmers participate in weather data so that they can appreciate the importance of water resources management. However, challenges may emerge when dealing with illiterate farmers who may not know numeracy and how to read. Nevertheless, weather prediction to take action and reduce harm to crops is a very important activity that supports decision-making.

Whereas farmers using the devices were selected on their merit, the devices were introduced to monitor soil water and nutrients. Two types were introduced the Chameleon soil water sensors and full-stop wetting front detectors. These devices helped to demonstrate to farmers how over-irrigating would negatively affect crop yields and incomes. Through the demonstration conducted on the schemes, farmers also learned that applying too much water than required leads to nutrient leaching influencing less nutrient availability within the root zone and becoming unreachable for the crops to absorb for nourishment. This knowledge influenced farmers to reduce irrigation frequency and interval, thereby significantly increasing crop productivity and creating more value for smallholder farmers. Technology availability is just one characteristic and does not show any innovativeness until its utilisation, however, once used it may add value to the irrigated farming system and reinforce the innovative capacity of the technology.

Risk preferences are the key factors of investment-based technology acceptability, adoption and use in the agricultural sector. Thus, for farmers to decide to take up new activities adopt and/or use new technologies are of fundamental importance for their success. Much of the decision may be reflected in the crop productivity change and income. According to Chavas and Shi (2015) technical and institutional risks as integral properties of agriculture. While Iyer et al. (2020) alluded to the fact that farmers are risk averse. Risk aversion is the propensity of people to favour results that have low uncertainty over those with high risks, even if the average result of the latter may be equal to or higher in economic terms than the more definite outcome. From the survey outcomes, some farmers indicated that they did not apply fertiliser or manure because they did not see the value. As they have seen and known the beneficial effects of fertiliser and manure that they can improve soil fertility, they can apply compost manure and chemical fertilisers to increase crop yields. The use of the devices has provided an impetus to many smallholder farmers who previously thought they were useless.

Many SIS are defective and have deteriorated over time. Thus, the evaluation and introduction of new technologies with subsequent farmer learning have been recognised to be essential requisites to facilitate sustainable transitions to more profitable irrigated farming. With the qualitative and quantitative data collected and analysed from the selected irrigation schemes, farmer learning has significantly contributed to a positive response about the role of devices. They stimulated a sensitive learning process and created a peer learning system. Furthermore, I learned how farmers changed their water application approaches, some farmers without the tools were imitating what their peers were doing, and farmer learning spread at different levels resulting in better extension coverage and governance. Some stakeholders facilitated insightful institutional change. Since knowledge generation and innovation are driven by the incentives of more profitable farming, then these devices have to be produced in abundance and cheaply so those poor farmers may be able to purchase them.

Availability of Innovative Equipment at Smallholder Farmer Capacity

Malawi is one of the least developed countries in the world and relies very much on imported technologies even though some can be manufactured or made in the country. However, the main obstacle to agricultural development concerns legal and bureaucratic hurdles to importing essential agricultural inputs (Team and Region, 2018). This research study involved the use of a Chameleon sensor and the fullstop wetting front detector relevant simple tools that can be used by illiterate people. The devices, as already noted, enabled farmers to transform their watering methods and enhanced agronomic practices One thing worth noting, however, is that these devices are manufactured in Australia and South Africa. Those that are currently used in the country are imported from South Africa. While the initial devices were given free, the manufacturers have put a price on them as numerous smallholder farmers after seeing their benefits would like to have them to boost their agricultural production.

Since irrigated farming has been carried out for decades or millennia, there is a diversity of soil water monitoring technologies that include gravimetric, neutron probes, psychrometers and tensiometers. These devices have helped farmers and managers alike in decision-making processes as to when to irrigate and at what interval or duration (Jones, 2004). Annandale et al. (2011) observed that the adoption rate of soil water technologies is low in Africa. As noted above, some of the reasons could be an absence of manufacturing industries, expertise to design appropriate technologies suitable for illiterate farmers and also less knowledgeable extension staff who cannot ably disseminate appropriate information to farmers (Stevens, 2006).

Stirzaker et al. (2017, 2014) under the auspices of the Commonwealth Scientific and Industrial Research Organization, Australia developed devices that could monitor soil water content and nutrient leaching for farmers who could not understand the quantity of water available within the crop root zone. The design was conceptualised to be easy to use and show colour lighting in the case of a Chameleon sensor and colour on a strip for the amount of solute in water collected by the full-stop and waterfront detectors. Besides, the developer considered that smallholder farmers would be learning from each other through shared information. The whole idea was to help the resource-poor farmers to make the best and most efficient water application decisions.

The working of the Chameleon is such that it is a soil water suction device that sucks water place at varying depths at different levels within the root zone having three sensors buried in the soil. Each array is connected to a reader that lights up showing three different colours green, blue and red. The farmers can understand the value of these colours facilitating learning about soil water and nutrient dynamics to support irrigation scheduling decisions. The Chameleon sensor measures the stress intensity at which they are placed in soil. Each sensor array depicts the colour light, where green is adequately moist, blue is wet, and red is dry. These colours show farmers' decisions on the duration and frequency of water application. The Chameleon demonstrates both under and over-irrigation. In addition, it helps farmers consider their fertiliser application strategies and agronomic practices.

As it is well known that the agricultural sector in sub-Saharan Africa is the largest water use, while agricultural water productivity is extremely low, it makes sense that these novel tools should be readily accessible to smallholder farmers. Accepting these tools after learning their relevance, adopting and using them could play a very significant role in improving water use productively and efficiently on smallholder farmers' plots on the schemes. Appreciating and accepting the enthusiasm of farmers to buy the devices to minimise water application and increase household profitability is necessary for household decision-making when planning and implementing the development of new irrigation schemes or renovating dilapidated old schemes. Consequently, this may help and support engineers and policy decision-makers to design state-of-the-art schemes and fitting policy tools for the wider interest of monitoring tools among resource-poor smallholder farmers. Understanding how to check soil water content level is indeed a basic skill for stallholder farmers on irrigation schemes and even more so during times of droughts. There are several honest ways of measuring it, however, this simple skill is regularly described in ways that only an irrigation engineer is usually competent in.

It is a critical view that many of the most challenging water resources management go beyond the conventional scope of analysis and governance. Water connects several sectors, places and ultimately people for domestic use and farmers for growing crops and spans across different geographic locations and temporal scales. To varying degrees, many nations have assigned progressively intricate and resource-intensive tasks to various departmental governments that result in interdependencies across agents of government that need harmonization to moderate division so created. Besides, projects designed to improve the socio-economic status of rural people, especially smallholder farmers who work across societal and governance levels need to consider some critical factors. Nonetheless, better crop yields are necessary for a profitable irrigated farming process that provides decent livelihoods for smallholder farmers.

New Knowledge Generated from the Research Study

After assessing the influence of farmers' learning on water productivity and profitability in SIS, the new knowledge the researcher has identified include the following facts presented below.

Using the simple soil water and nutrient monitoring devices, can improve water use efficiency that leads to water, time and fertiliser reductions and improved crop yields as well as sharing information. Since the introduction of the devices, farmers have been sharing information observed from the sensors with peers in their schemes, permitting them to manage and distribute water fairly. They also share experiences and best practices for improving water productivity and profitability.

Improving knowledge and skills through learning through which farmers share experiences in water resources utilisation are important to better manage weather variability and climate change. Netshiukhwi et. al., (2013) claimed that scientists and illiterate smallholder farmers use different means to predict weather conditions and envisage a possible behaviour of climate in the growing season. However, if the illiterate farmers participate in learning they can be on the same page with literate and scientist to identify change in soil water content. Game-changing developments in water scarcity, water use efficiency and soil water and nutrient monitoring technologies are emerging every day that can improve food security and increase household profitability. Thus, farmer learning improves knowledge of water management that can lead to behavioural transformations and quantifiable advances in irrigation productivity.

Using sensors to monitor soil water content and nutrient leaching can assist farmers recognise irrigation-related challenges and problems and act on the acquired information successfully. However, this research has acknowledged that farmers' understanding of water productivity differs. While some consider using the devices to promote the efficient use of water, and others consider it to support good crop harvests.

Regarding factors influencing the technology adoption, socio-economic and demographic factors, and spatial variability in biophysical characteristics are important and very relevant. Such that the policy- makers and the government should understand very well when creating new policies. Since the devices though simple and important the government should favourably consider farmers to have access to credit to procure the devices. Absence of financing and access to credit may inhibit farmers from acquiring adequate inputs

Recommendations for Future Research

Burney et al. (2013) proclaimed that governments and donors worldwide encourage stimulating irrigated farming to food security and reduce poverty, particularly in the poorest areas. According to Mutiro and Lautze (2015), 40% of the irrigated farming systems carried out in the Southern Africa Region are categorised as ineffective, particularly regarding government-managed schemes. The major reason for ineffectiveness was not necessarily in Africa only but the world over. The government-managed irrigation systems exposed a persistent incapacity to improve expenditure spent by smallholder farmers (Waalewijn, 2013).

Implicitly though, the shortfalls which were a result of subsidies had to be included in the government's fiscal budgets. The rising responsibility of these subsidies is noted to be one of the sources of government financial challenges that forced and influenced governments in many countries to consider prudent ways to make the beneficiary farmers of irrigation take greater charge and accountability to manage and meet the costs for water delivery facility maintenance. This meant that the governments would transfer the management of the irrigation schemes to farmers, institutions and organisations available on irrigation schemes. The most typical reasons that *governments* would want to *transfer the management* responsibilities to smallholder *farmers* on irrigation schemes are *government* failures to finance and meet *irrigation* costs.

The expression 'irrigation management transfer' entails the repositioning of, accountability, responsibility and authority for irrigation management to move from government agencies to either non-governmental organisations such as water users' associations or farmers themselves (Bedore, 2008). A general intention for the attempted transfer in most of the countries appears to have been the inability of the state to cover operation and maintenance costs. With a few notable exceptions, the focus of individual smallholder scheme transfer experience was on the transfer benefits. Several irrigation gurus have suggested that irrigation management transfer changed from its fundamental intentions of attaining food self-sufficiency and refining the farmers' livelihoods to decreasing the state's financial burdens (Nizamedinkhodjayeva, 2007).

The crucial concept for promoting irrigation management transfer was that farmers themselves should consider irrigated farming as a business entity that should make profits. Some Research studies conducted examined the mode of transferred management in scheme operations whether they were managed by a group of farmers or in partnership between farmer and state-managed schemes (Danso-Abbeam et al., 2018). As a consequence, any instruments and devices that are supposed to be used for improving farming crop productivity should be the responsibility of farmers.

The narrative given above endeavours to justify the recommendation for the future in terms of the use of soil water and nutrient monitoring tools. These devices have proven to be game changers in crop productivity and profitability for those households practising irrigated farming. People's use and management of soil and water resources have shaped through millennia the growth, determination, deterioration, and regeneration of civilizations that have been sustained with soil as the foundation of agrarian systems (Parikh and James, 2012). Increasing access to water for smallholder irrigation farmers in Sub-Saharan Africa generally and Malawi in particular, is a challenging issue. This could be because of initial investments in implements and devices used for supplying water and determining soil water content respectively on the smallholder farmers' irrigation schemes that range from buckets, treadle pumps, motor engines etc.

With unprecedented human population growth with the consequence of changing food consumption preferences and patterns, experts have projected that there is an urgent need that necessitates doubling food production in emerging countries by 2050 (Bhaduri and Manna, 2014). They suggested that 80% of the food demand would have to come from higher crop productivity, and greater crop intensity with given limited scope for agricultural land expansion and approaches to increase water use efficiency. Expanding and intensifying the use of more efficient irrigation systems and agricultural water management technologies is one of the key issues in solving crop productivity challenges sustainably. Currently, only 5% of land in Africa is under irrigation. Thus, if investments in efficient irrigation instruments can vigorously be supported, this can lead to the most important improvements in the living standards of smallholder farmers who produce the majority of food crops in developing countries (Mapila, 2021; Smith et al., 2014).

Intensifying people's livelihood resilience from threats and disasters creates one of the tactical intentions advanced by the Food and Agricultural Organisation's Strategic

Framework's strategic objective number. The organisation particularly intends to build resilience in the agricultural sector associated with food and nutrition security. The agricultural sector is among the sectors most harshly influenced by natural hazards such as Cyclone Idai that recently ravaged the Southern African Region (Kalanda et al., 2021). The effects of shocks and disasters can be eased and rescue can be significantly facilitated if proper farming practices are put in place; enlightening the capacity of communities, local institutions and authorities, as well as other stakeholders, is, therefore, fundamental to resilience edifice.

To circumvent many of the challenges that smallholder farmers face in developing countries is a dearth of knowledge and awareness of new technologies. In developing countries, one finds the majority of the poorest and undernourished citizens living in rural areas with poor facilities. Their main occupation is often agricultural activities for livelihood. The agricultural sector plays an important function, not just as a food security source and household income, but also contributes significantly to the country's economic development. The agricultural sector in Malawi contributes over 38% of the gross domestic product and employs over 85% of the labour force. Despite an annual growth rate of nearly 3%, the remainder can be characterised by practising traditional methods that hamper bringing new changes in contributing to the creation of wealth and jobs. The low adoption of innovations in the agricultural sector may be linked to several factors.

For example, some technology that may be deemed to be new may not be profitable from the farmers' point of view after trying it, besides, this could be the availability of requisite institutions and infrastructures that are lacking to support the initiatives. Another important factor is the shortage of adequate money for farmers to acquire the technology even if it has been proven to be profitable. Due to risk aversion, smallholder farmers may be unwilling to try new technologies (Wiggins, 2016). Based on the above circumstances, mounting or conducting demonstrations could be one way of training, teaching and also creating awareness of various agricultural techniques and technologies that can change the smallholder farmers' way of living. Demonstration, furthermore, can showcase new technologies and also improved crops by serving as conduits or channels through which researchers can test and compare results about new technologies alongside conventional ones. Another point worth exploring concerns the need for upscaling the new agricultural technology. According to Nakano et al. (2018), farmer-to-farmer interaction cannot be underrated because technological change can be influenced through peer discussion as a necessary and vital consideration for the development process. Malawi since independence has promoted the smallholder sector to improve agricultural production. It has collaborated with several national and international partners to address this issue of low crop productivity.

Training programmes have deliberately been organised and many smallholder farmers have benefited from such training sessions and technology demonstration programmes. A vivid example is a demonstration that has been conducted in some irrigation schemes on the relevance of increasing water use efficiency and crop productivity by using soil water and nutrient-motoring tools (Fandika et al., 2019; Kissawike, 2008). In this regard, another future recommendation is that training sessions and demonstrations have to be organised in those irrigation schemes that did not have the opportunity to see and use them. For some, field visits could be made to those schemes that have been using the devices to gain what they can do.

Social and/or Farmer Learning Inclusion

This research study concerned farmer learning that considered social inclusion to be a relevant issue. Farmer learning at the smallholder level could be considered as the process by which communities and farmers alike could cooperate to combat food security and poverty. The research findings observed that some farmers were not taking part in meetings thinking that the meetings were for those selected to use the monitoring devices. For policies in irrigated farming to be thoroughly established and applied to work against social inclusion, factors such as illiteracy, poverty and gender have to be clearly understood (Mudege et al., 2017). Literature abounds regarding how gender relationships manipulate male and female farmers' right of entry to and joining the irrigated farming training programmes. Some reports have examined how male and female farmers justify or challenge gender inequalities in terms of access to information and knowledge about available technologies that may have positive impacts on their households (Leta et al., 2018; Beuchelt, 2016).

Crop Water Use Effects on Crop Productivity and Profitability

Water resources management is a very important factor in irrigated farming. Many people do not realise the importance of appreciating the soil-plant-atmosphere-water continuum and the requisite processes of how crops absorb water and consequently use it. Crop water utilisation is affected by such factors as water use efficiency. Crop water use can be defined as water uptake used by a crop for transpiration, metabolism, growth and development (Brendel, 2021). It is a dynamic process that is influenced by climate, soil and plant factors through the soil-plant-atmosphere continuum. In many training sessions for farmers, this topic is not presented and with the new technologies being promoted it can be of value if this could form part of the training programme by shortening the contents by providing the relevant materials, particularly climate variability and the tools that can be used to estimate and measure crop water use.

Irrigation Infrastructure Maintenance and Farmer Involvement

In irrigated farming, there are three types of irrigation systems: sprinkler, drip and surface irrigation. Their appropriateness relies on the natural conditions that include the type of soil, landscape configuration, climate, water availability and quality as well as the farmer's potential investment. According to Hajra and Williams (2020), most smallholder irrigation farmers adopt the surface irrigation system because it is relatively cheap and does not require huge investments, unlike sprinkler and drip irrigation systems. What is crucial with a surface irrigation system is the field irrigation efficiency, which is strongly dependent on conveyance, application and crop water use efficiencies. Since irrigation entails the application of water to meet crop water requirements, it is, therefore, important that farmers should be able to monitor or estimate crop water use so that they base their scheduling on accurate evidence of soil water availability. This activity is to inculcate in the farmers' minds water deficits or excesses, with the latter as a major source of environmental pollution (Kumar, et al., 2021). Further attention is directed to climate change realities which may negatively affect both surface and groundwater storage.

Institutional Involvement in Water Resources Management

Climate change has been acknowledged to have worsened global conditions by modifying hydrological cycles, which have made water availability to be more unpredictable thereby increasing the frequency and intensity of floods and droughts. Reports indicate that flood damages have been estimated to be $120 billion per year considering property damage alone, whereas droughts affect, among others, limitations to the rural poor who are hugely dependent on rain-fed agriculture for subsistence (Kumar, et al., 2021). To strengthen water resources management and security against the backdrop of increasing demand, water scarcity, growing uncertainty, greater extremes, and fragmentation challenges, farmers at SIS need to invest in institutional strengthening, information management, and infrastructure facility development.

Institutional tools such as legal and regulatory frameworks, monetary contributions, and incentives are required to better apportion, legalise, and support appropriate water resources management initiatives (Mumseen and Saltiel, 2018). Information systems are required for soil profile water content monitoring to make decisions under uncertainty as well as making irrigation systems analyses, and hydro-meteorological forecasts and warnings. Thus, financing the procurement of innovative technologies for improving crop productivity, conserving and protecting water resources cannot be overemphasised. Thus, in future, it is encouraging to ensure that there must be rapid dissemination of information on irrigation schemes for suitable adaptation or application of the advances as a key to strengthening scheme water security. An accurate message should be prepared and disseminated to every member of the scheme to keep abreast with new developments.

As noted from the respondents’ narratives, their increased crop production and attainment of actual water savings on their irrigation schemes were dependent on the knowledge, awareness and understanding of all users including farmers, scheme managers and scheme committees. This meant that for successful outcomes intensive training and regular meetings are required and necessary. Many farmers have now accepted the concept of water users’ associations as key participants in the management of water delivery services and conflict resolution.

Conclusion

According to the field survey that was conducted between May and June 2021 to assess water productivity and profitability through farmer learning in selected SIS in Malawi, some salient gaps were identified, particularly the need for incessant monitoring and higher data quality collection for longer-term assessments as to how water use efficiency intervention has impacted on the household food security and incomes. There is also a swift requirement to develop and apply a methodology for classifying each of the water use efficiency interventions according to the impact on the performance of irrigated farming practices.

Soil water and nutrient measurement are important procedures that help and support irrigation scheduling (Gu et al., 2020). Current irrigation water management research has emphasised the relevance of integrating soil water and nutrient monitoring as a crucial input in variable rate irrigation management simulations as claimed by (O’Shaughnessy et al., 2015). Variable rate irrigation tolerates varying the rate of water to be applied on farmers' field plots to befit the crop water requirement based on the soil type and how the farmer carries out his/her operations. By accepting and modifying some farm inputs and outputs, the farmers can capitalize on crop productivity, reduce some key costs that may not be relevant at that time and contribute to the reduction of nutrient leaching and water losses.

These devices provide point measurements of soil water and nutrient leaching similar to conventional soil water measuring techniques. Such point detection may not be representative of total farmers' field plots. It only measures soil water and nutrient leaching on sub-areas of field plots if the selection was poorly done. Notably, though, the installation of dense soil water sensors for irrigation management is unfeasible from the economic, logistical, and data management points of view. The research study intended to find the relevance and patterns of success and failure of extension service delivery. This involved simple qualitative and narrative comparative analysis. The findings revealed that several issues comprise access to extension, services by water users' association, prevailing social capital, security of land tenure, effects of user organisation and their activities. However, the detailed assessment of the selected schemes revealed findings that are mixed and not unclear, however, there appears a coherent pattern emerging that suggests a recipe for positive and effective application of the soil water and nutrient monitoring devices.

The influences of climate change have been observed, in general, changing water availability. As such the effects will be based on locality and periodicity variables. Changes in extremes of water scarcity may lead to changes in drought frequencies, their magnitudes and durations thereby affecting the welfare and livelihoods of the smallholder farmers. On the contrary, water availability has consequent negative outcomes on farmers' household food security and income. It is, therefore, important that the devices can play very significant roles in informing those farmers who engage in irrigated farming to consciously use and apply adequate water that could help harvest bumper crop yields.

Considering or recognising that soil water content is indispensable for water resources use and management is key to successful household crop productivity and food security. The scientific field for soil water content is well developed, however the instruments for sensing soil water content are undergoing rapid change, and the number of sensor choices has significantly increased. The reliable and well-understood tensiometers are being replaced in many situations by technologies based on the electrical properties of soils and user-friendly by uneducated people. However, such systems are subject to many interferences related to the soil bulk electrical conductivity that is extremely variable in time and space for many soil types (Datta et al., 2017). It is of this view that soil water sensors should be evaluated for accuracy and calibrated if not within the acceptable ranges for the intended use.

This research did not pursue any demonstration rather it was designed to find out from respondents what they learned from using and not using the soil water and nutrient monitoring devices. The study pursued to get responses and answers from farmers on the relevance of introducing the farmer user-friendly devices to a few farmers on the schemes. While the farmers were informed what the colours on the Chameleon tool meant, there was no indication of the values of the colour patterns they had to aim for. The objectives were to identify from the farmers whether the device's role of revealing the presence of water in the soil profile was obvious and relevant. If the water application was too much it meant that the farmers were losing out on crop nutrient availability as excess water removes the nitrates along with it. For the dry soils, it meant crop stress thereby promoting crop low yields at the end of the growing season. More importantly, this was based on farmer learning through interaction regardless of socioeconomic status even though it came naturally. The main reason was whether the stallholder farmers could, by themselves, understand and appreciate the information and may do something to change the soil conditions. If this could be done, the farmers could create relevant assessment protocols for their benefit and the irrigation scheme as a whole. In most cases, there are more issues with SIS that deal with governance and the presence of institutions is crucial to solving available challenges and problems.

The influences of climate variability will vary in water availability both in space and time generally. The climate effects are generally observed at spatial and temporal le of variables. Extremes water scarcity will increase changes in drought frequency, magnitude and duration. Climate variability will upsurge the water demand, particularly for irrigated farming in drought-prone areas that are already under pressure. Climate change will also change the extent, incidence, distribution (spatially and temporally) and duration of flood occasions and may even lead to the loss of land on floodplains where mots irrigated farming in Malawi is carried out. Flood waters are both damaging and hardly available for use in agriculture.

The spatiality of smallholder irrigated farming is an equally important intention that influences people to venture into businesses from the realised profits. Based upon this research study's findings, the youth who are not eagerly involved in irrigated farming should be encouraged to take up irrigated farming and should be included in their both primary and secondary education curriculum, as this will increase the chances that they develop ambitions of venturing into agro-entrepreneurship. Agro-entrepreneurship involves the steps needed to grow agricultural crops and prepare them to send them as agricultural goods or commodities to market, consequently, it involves production, processing, and distribution.

When initiatives are available, wherever possible, the main purpose is to increase youth participation so that they can be able to design appropriate irrigated farming initiatives can provide training on how to reduce climate risks. Although very few youths are participating in irrigated farming as this study found, the anticipation of such services can inspire the younger generation to engage in farming businesses. To the economic perceptions of the younger respondents, the research found agro-entrepreneurship to strongly influence the intention of the youth to participate in irrigated farming. This idea should be encouraged to raise awareness of irrigated farming's lucrative business and the creation of better remunerative employment opportunities that the agricultural sector submits to draw more members of the youth into Agro-entrepreneurship.

Plans for refresher courses to train extension officers in water scheduling should recognise the value of smallholder farmers' local knowledge. The farmers know their soils and the trainer should ensure that water application is part of irrigation knowledge that the agricultural extension training should not leave out. If lead farmers are involved in the training sessions, it would be more suitable if learning and support were offered in their scheme. This would avoid the need for travel expenses, reduce costs incurred by farmers, and also lessen the mistrust created by such farmers. Smallholder agricultural practices are both intricate and vibrant, such that farmers are continuously required to react to new challenges involving social, economic, environmental and political changes. The research findings reveal that farmers in all the irrigation schemes are persistently testing, adapting, innovating and investigating how these devices shall transform their welfare and also identify novel and improved means of crop production and organisation to address the challenges they experience.

The novel technologies that are introduced are mostly driven by a variety of intertwined issues such as socio-economic factors, and the incapacity to pay for farm inputs or grow sufficient food to be food secure where land scarcity is the challenging characteristic due to unprecedented population growth (NSO, 2019). Another factor concerns the environmental situation that calls for a need to adapt to climate variability or rejuvenate infertile soils that have not been rested due to small landholdings. Socioeconomic factors play a very significant role in irrigated farming. Most families in rural areas have been affected by HIV and AIDS which has contributed to less labour availability (Wiegers, 2008). Additionally, cultural factors have contributed to many people dying because of the need to use certain plants for rituals and other purposes to cure HIV and AIDS. According to Flint (2015), customary healing procedures have remained an important part of many cultural engagements with healthcare, particularly HIV/AIDS treatment has not been spared. If these devices reduce the time to irrigate their crops when there is a patient, then there is a positive chance that the sick could be properly looked after and cared for. Irrigation is a time-consuming activity often taking up a whole day to complete.

The last aspect concerns political factors. From the research findings, most of the respondents indicated that there were no credit facilities and availability of subsidised fertilisers and seeds. It may be noted that the factors of farmer innovativeness are difficult to separate. Whereas some farmers transformed their farming practices out of necessity, harsh conditions or prospects, others consider a much more organised approach to farming revolutions, such as the smallholder farmers who, after the farming season, analyse their farming outcomes as a way to improve upon those areas that did not do well in implementing their farming practices.

The topic of enhancing crop productivity using reduced water application can be considered to be new to smallholder irrigated farmers. However, the idea of crop productivity is not entirely new to farmers. Smallholder farmers have their crop productivity definitions and how they are measured. Smallholder farmers consider crop productivity based on rainfall amount and its influence on crop yields. Nevertheless, crop productivity in terms of reduced water availability is either high or low if the average seasonal rainfall is good or bad respectively. Most often smallholder farmers value water very much because they know that crop yield is related to water consumption. As climate change and variability are showing their influence, many smallholder farmers are developing small irrigation schemes to avert household food insecurity.

Smallholder farmers value water very much because they know that crop production is related to water ceteris paribus. Most often farmer conflicts result in fighting just because someone diverted water that was not meant for his/her plot but instead irrigated his plot.

Additionally, some farmers are willing to divert more water if their fields are located at the head (top), close to the water source and can easily divert it to irrigate their fields without knowing that applying too much water can leach out the expensive fertilisers applied. It was also noted that the water bailiff sometimes is corrupted as others give some money to give them more water. People believe that if too much water is applied then they would get a higher crop yield. With the devices, this allegation has been proven wrong in the selected schemes. Most smallholder Farmers have known that they can maximize crop productivity if water is reduced and within the root zone of crops. Meaning that the crop productivity concept of water is all about efficient water use.

Their schedules aim to achieve crop productivity and respond to water shortages as a result of climate variability (Vitsitsi, 2019). Based on information the scheme manager may provide as a forecast, the farmers may be trained on how to plan and strategise how they would apply water to get the best crop yields. They are very conscious of the amount of water they use in crop production, even though they do not keep records. They have good visual capability to estimate available water and how it can be shared across the season to maximise crop yields. Many farmers as well as *others* are realising that not too much water is required to grow crops on irrigation schemes and there is a revolution and inspiration that many want to participate in irrigated farming (Mapila, 2021). This growing demand to participate in irrigation learning is influenced by increasing water use efficiency through the use of innovations like the Chameleon and waterfront detectors, which attempt to solve many water supply development challenges at the same time, which are generally required. Improving crop productivity that directly or indirectly affects household food security and incomes can be responsible for driving growth in meeting most of the Sustainable Development Goal goals. Strategic water application innovations can quicken the progress towards 2050 and beyond.

The study evaluation as one of the last issues to be crucially noted draws attention to some restrictions and missed opportunities in the current manner in which the novel devices were introduced to stimulate farmers on how well they can available water resources in line with the country's overall national policy goal that seeks to contribute to sustainable socio-economic growth and development through improved irrigated farming and household productivity (DoI, 2016). Therefore, the following points should put into picture the concepts, plan, design and implementation of future water resources efficiency interventions on SIS in Malawi.

Future smallholder irrigation interventions and initiatives should consider increasing local farmers' input regarding the type of individuals to participate in the novel technology's experimentation. The inadequacy and experiences with soil water and nutrient monitoring devices accentuate the essential requirement for pre-testing with very few poor uneducated farmers about the new technologies and consulting communities before they are fully introduced. Of the most salient factors, the device infrastructural designs should look beyond their durability in terms of sustainability options to be consistent with the poor smallholder farmers' operation and maintenance systems. More precisely, the investment in these novel irrigation technologies should be driven by key dual questions: "Will the farmers be able to succeed with the irrigated farming systems reasonably well without extra support after the project advocates have pulled out after the project?" and "Can the sensible and tangible investments concerning the monitoring devices change or disturb local governance, facility maintenance arrangements and, negative implications with water distribution equity?" So, if the technology to be introduced provides answers to the former negatively and the latter positively, then the decision to be made is that it is not worth considered to be helpful and therefore it can be disapproved and therefore rejected.

Availability of institutions on SIS is a "must" for future intervention to help in the availability of farm inputs, credit and marketing facility presence as beneficiary smallholder farmers need support systems that extend far beyond their irrigated farming borders if they are to considerably advance their livelihoods. This is crucial and decisive to suggest that the water users' association support a more impartial distribution of water supply as this role is also consistent with the national irrigation policy's managerial values. Notwithstanding this, there is diminutive focus or detail specified about how the impartial water resources delivery to smallholder field plots could be achieved without well-organised water users' management systems.

Last but not the least, future support for farmers to adapt favourably after water scarcity, the findings have shown where there is no regular water facility distribution maintenance there shall be unequal water distribution. Forcing water distribution through such dilapidated infrastructure, weak and unskilled repairs will not resolve water scarcity for many tail-end farmers if this happens at the headwater distribution point. In such cases, it has been noted in the schemes that farmers change their cropping patterns, crop selection, and even use shallow wells for groundwater pumping rather than engaging in systems maintenance.

Photo 5.7 Shallow Well on a Smallholder Irrigation Scheme

Some farmers suggested that for future water use efficiency interventions, in some schemes it could be neither obligatory nor conceivable to form and tolerate formal local organisations that are necessarily focused on irrigation water resources management. This allegation is based on the fact that in some societies considered by varied livelihoods and slightly profitable irrigated farming, it may not be valuable for farmers to invest heavily in management associations such as water users associations for fear of corruption (Kissawike, 2008). In such situations, the use of prevailing versatile local organisations, like village development committees can be mandated to manage irrigation water resources management and could be a more sustainable option.

Strengthening access and refining market systems by providing extension and technical support to smallholder irrigated farmers is one of the most crucial issues that is urgently required. Most farmers in irrigation schemes sell their products to vendors at low prices. Thus, future interventions to improve crop productivity and increase water use efficiency can also have a huge influence on irrigation schemes by bridging the divide between farmers and agricultural agencies in terms of marketing.

All scientific advancements have evolved through the steady growth of knowledge. While assuredly motivated, Einstein's prototype principle that associates energy with a role of mass and velocity was not just developed out of nowhere (Rao, 2013). His ingenious vision was grounded on a fusion and expansion of the accessible facts of that time. Since Einstein discovered his formula in 1905, there has been no clear experimental evidence that has been recounted on the superluminal speed of electromagnetic radiation, for example, X-rays. Besides, there has been no clear theory proposing electromagnetic radiation superluminal swiftness at specific wavelengths. This discourse is made to substantiate the fact that the devices have stories that can be narrated in agreement with how they work and can be repeated.

Summary

It is noticeable from the research findings that there are occasions where there is a straightforward link between soil water content and crop yields according to the way farmers applied water to the soil based on the tools, imitation and conventional manner. In some occasions, there is no direct causal relationship, however, the narratives from the farmers provide some positive explanations that the tools have changed the way they apply water. They never knew that applying a lot of water was injurious to the crops. Besides, several crop management factors influence crop production if water resources are used effectively and efficiently. The obvious discrepancies that some farmers said particularly in the Bwanje Valley Irrigation Scheme, the crop productivity in some farmers' plots are not simple to enlighten. It can be noted that Chameleon readings were sometimes not carried out frequently by the farmers and research assistants employed to record the readings due to incidences that were beyond their control such as funerals. Comprehensive records of soil water content and nutrients in the root zone and crop management practices would have provided a stronger picture of the water use efficiencies and their influence on crop yields. These primary findings require further studies.

This research was conducted as mixed-method research integrating qualitative and quantitative approaches to provide narratives from the farmers' perspectives and was not experimental research. The essence was to understand whether farmer learning using soil water and nutrient monitoring tools benefitted in terms of solving food security and acquiring more income from applying less water and increasing crop productivity. Thus, the main purpose was to appreciate the value of user-friendly tools to a group of smallholder farmers in irrigation schemes that were selected and get information on whether the devices helped to solve water scarcity challenges and problems, for instance, plots that were not regularly irrigated and the soils were dry, soil nutrients were leached and whether farmers understood the relevance of the colours displayed on the Chameleon. Additionally, this study intended to understand farmer experiences in water resources management through interactive learning in a deliberately conducive learning environment.

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APPENDICES

Appendix A: Letter of Introduction to Conduct Research

Yahoo Mail/Inbox
Elisha Vitsitsi
From: gvitsitsi@yahoo.com
To: Geoffrey Mwepa
Fri, 9 Oct 2020 at 11:31

Dear Geof,

Please find an attached letter from Unicaf University regarding research activities I would like to do in some selected irrigation schemes. This also refers to my earlier communication on the same. Your favourable consideration is therefore sought. For the itinerary I shall provide the details after your communication.

Regards and God Bless.

Elisha Vitsitsi (R1802D4533932) Confirmation Letter for PhD Thesis UUZ.pdf
131.7kB

Elisha Vitsitsi
From: gvitsitsi@yahoo.com
To: gmwepa@gmail.com
Fri, 9 Oct 2020 at 11:53
I sent you below. Please acknowledge.
Show original message

Elisha Vitsitsi (R1802D4533932) Confirmation Letter for PhD Thesis UUZ.pdf
131.7kB

Geoffrey Mwepa
From: gmwepa@gmail.com
To: Elisha Vitsitsi
Cc: Geoffrey Mamba
Fri, 9 Oct 2020 at 12:17
Elisha,

You are welcome to do the research.

Show original message

All communications should be addressed to

Department of Irrigation
P. O. Box 30797,
Capital City,
Lilongwe 3
MALAWI

May 24. 2024

DIRECTOR OF IRRIGATION SERVICES

Unicaf University
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Attention: The Registrar

Dear Madam,

RESEARCH APPROVAL LETTER FROM THE DEPARTMENT OF IRRIGATION

We write to indicate that on October 9, 2020, Dr Elisha Gerry Jostone Vitsitsi contacted us that he wanted to conduct a research study in some Smallholder Irrigation Schemes in Malawi and shared with us a letter from the Registrar Ms Selia Masoura and his research topic was entitled, "Assessing water productivity and profitability through farmer learning in selected smallholder irrigation schemes in Malawi." This research topic was relevant to improving farmers' productivity and profitability of irrigated farming. The study has the potential to make a significant impact on the livelihoods of smallholder farmers in Malawi as well as in other countries particularly in Sub-Saharan Africa where climate change is significantly being felt and we were pleased to support it.

We confirm that Dr Vitsitsi was allowed to conduct the research in three selected schemes in which some smallholder farmers received Chameleon Sensors and Wetting Front Detectors to monitor soil water and nutrient content. The schemes included Bwanje Valley, Tadala and Tiphunzire Irrigation Schemes in Dedza District and Khamalathu and Mulunga Irrigation Schemes in Chikwawa District.

We are looking forward to the findings and recommendations of the study so as to use them for improving productivity of the schemes.

Yours sincerely,

Geoffrey Mwepa
DIRECTOR OF IRRIGATION SERVICES

9th October, 2020

To Whom It May Concern

This letter serves as confirmation that Elisha Vitsitsi with student ID number R1802D4533932 is currently enrolled in the Doctorate of Philosophy programme of Unicaf University in Zambia.

The student is currently undertaking research for the Dissertation, on the below topic:

'*Assessing Water Productivity and Profitability through Farmer Learning in Selected Smallholder Irrigation Schemes in Malawi*'.

If you require any additional information or clarification, please do not hesitate to contact us in the first instance.

Best regards,

Ms. Selia Masoura

Registrar

Office of the Registrar

Unicaf University:
Plot 20842, Off Alick Nkhata Road, Longacres, Lusaka, Zambia
Telephone: +260 211250522 **Email:** info@zambia.unicaf.org
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Appendix B: Questionnaire: Household Questionnaire for User-Friendly Soil Water Monitoring Devices in Selected Smallholder Irrigation Schemes in Malawi

Household Questionnaire **Code**: [| |]

Research Assistant .... Principal Investigator ....

Date: (dd/mm/yy) [/____/_____/_____/

Instructions: Please write some answers in the boxes for each question on the papers. Four parts are covering the main issues on 14 pages. **PLEASE CHECK**!

Courtesy Remarks for Research Assistants to the Farmers

1. Thank you so much for your willingness to participate in this study.
2. I also thank you for your time and cooperation.
3. Your responses are kept confidential.
4. The information collected will be used for research purposes only and nothing else.
5. The idea is to improve how you use water and get benefits.

Background Information

1. Household ID ______________________________
2. Village ______________________________
3. Group Village Headman ______________________________
4. Traditional Authority ______________________________
5. District ______________________________
6. Scheme ______________________________
7. Interviewer ______________________________
8. Date of Interview ______________________________
9. Time Started ______________________________
10. Time Ended ______________________________

Part I: Farmer Household's Socio-Economic Characteristics

Please answer the following questions based on the instructions for each question

A: Background Information

Item	**Issue**	**Unit**	**Answer**
1	Respondent's relation to the household head: Self = 1, Spouse[1] = 2, Parent[2] = 3, Child[3] = 4, Grandchild=5	Code	
2	Gender: Male = 1, Female = 0	Code	
3	Age	Number	
4	Education (Literate): Yes = 1, No = 0	Code	
5	If yes, Primary School = 1, Secondary =2, Tertiary = 3	Code	
6	Household Head Marital Status: Married = 1, Married Spouse Absent = 2, Single = 3, Divorced = 4, Separated = 5, Widow(er) = 6	Code	
7	Household size	Number	
8	Number of Children	Number	
10	Children attending school: Yes = 1, No = 0	Code	
11	Number of Dependents	Number	
12	Religion: Protestant = 1, Catholic = 1, Muslim = 3, Pentecostal = 4, Other = 5	Code	

B: Physical Assets

Item	**Issue**	**Unit**	**Answer**
1	Landholding: Yes = 1, No = 0	Code	
2	Total farm size	Ha	
3	Number of own plots of land?	Plots	
4	Number of land ownership years: 0-1=1, 2-5 = 2, 5-10 =3, > 10	Code	
5	Land rent: plot size	Ha	
6	Easy of land acquisition: Easy = 1, Not easy = 0	Code	
7	Cost of rent	Number	
8	Let out to others	Ha	
9	Farm implement: Yes = 1, No = 0	Code	
10	Type of implement	Name	
11	Type of dwelling house: 1 = Rammed earth = 1, Unburnt brinks = 2, Burnt bricks = 3	Code	
12	Type of roofing: Thatch grass = 0, Iron sheet = 1	Code	
13	Number of rooms	Number	
14	Household status: Very Poor = 1, Poor = 2, Good = 3, Very good = 4	Code	
15	Radio: Yes = 1, No = 0	Code	
16	TV: Yes = 1, No = 0	Code	
17	Mobile phone(s): Yes = 1, No = 0	Code	

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[1] *Wife, Husband, Partner*
[2] *Mother, Father*
[3] *Son, Daughter*

C: Farming Experience

Item	Issue	Unit	Answer
1	Crop grown: Maize = 1, Rice = 2, Sugarcane = 3, Vegetables = 4	Code	
2	Area grown	Ha	
3	Farm experience (years): <10 = 1, 10-20 = 2, > 20 = 3	Code	
4	Farming experience: Parents = 1, Other farmers = 2, Extension service = 3	Code	
5	Harvested crops	Name	
6	Yields	Kgs	

D. Membership in Scheme

Item	Issue	Unit	Answer
1	Member of an irrigation committee: Yes = 1, No = 0	Code	
2	If Yes: WUA = 1, Co-op = 2, Both = 3	Code	
3	Time as member	Number	
4	Position: Chairman = 1, Secretary = 2, Committee member = 3; Scheme member = 4, Other specify = 5	Code	
5	Reason of being a member: To get information quickly = 1; To get credit = 2; To get valid crop prices = 3	Code	

D: Labour

Item	Issue	Unit	Answer
1	Family labour availability: Yes = 1, No = 0	Code	
2	Adequacy: Not adequate = 1, Just enough = 2, More than adequate = 3	Code	
3	Off-farm work (*ganyu*): Yes = 1, No = 0	Code	
4	Remittances, wage/employment, social cash transfer	MK	
5	Alternative sources of household income or livelihood: Yes = 1, No = 0	Code	

E: Livestock

Item	Issue	Unit	Answer
1	Type owned: Cattle = 1, Small ruminants[4] = 2, Pigs = 3, Poultry = 4	Code	
2	How many	Number	
3	Sale from livestock (milk, eggs)	Number	
4	Manure use: Yes = 1, No = 0	Code	
5	Availability of grazing land for animals over the last two decades: Yes = 1; No = 0	Code	
6	Widely prevalent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree=4, Strongly agree=5	Code	
7	Availability of water for animals over the last decades: Yes =1, No = 0	Code	

[4] *Goats, sheep*

8	Widely prevalent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
9	Impact of livestock on livestock (all kinds of animals): Yes = 1, No = 0	Code	
10	What impact: Price = 1, Theft = 0	Code	
11	Widely prevalent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	

F: Farming Activities

Item	Issue	Unit	Answer
1	Farm record maintenance: Yes = 1; No= 0	Code	
2	Crops grown (name as many as possible)	Name	
3	Preferred crops are grown for income generation	Name	
4	Varieties planted for the above crops	Name	
5	Tillage method practiced during land preparation: Hand = 1; Hand tiller = 2, animal drawn plough = 3, Tractor plough = 4	Code	
6	Source of inputs (seeds, fertilizers, chemicals): Local shops = 1, Agro-dealer = 2, Government = 3, Other = 4	Code	
7	Type of fertilizer use?	Name	
	Transport costs do you incur while sourcing for these inputs	MK	
9	Crop yield from a plot	Kg	
10	Price per kilogram of produce	MK	

G: Irrigation

Item	Issue	Unit	Answer
1	Irrigation farming practice: Yes = 1, No = 0	Code	
2	Irrigation system used: Furrow = 1; Border = 2, Sprinkler = 3; Drip = 4	Code	
3	Area of irrigated land	Ha	
4	Irrigation water source: River = 1, Groundwater/Shallow Well = 2, Both surface and ground water = 3, Dam = 4	Code	
5	Challenges in irrigated agriculture: Yes = 1, No = 0	Code	
6	Water scarcity = 1, Soil fertility = 2, Labour availability = 3	Code	
7	Plans to adopt an irrigation innovation Yes = 1, No = 0	Code	
8	If yes, reasons to adopt an irrigation innovation: Irrigate sufficiently during water scarcity = 1; Improve yield and crop quality = 2, Increase land value = 3, Reduce water application = 4, Labour = 5; Energy cost = 6, Soil erosion = 7	Code	
9	Purpose of irrigation innovation: Tools for measuring water application = 1, nutrient leaching = 2, Both water application and nutrient leaching = 3, Other specify = 4	Code	
10	Yield of crop	Kg/ha	
11	Amount of water applied (estimated)	Ls	
12	Knowledge of water application: Soil dryness = 1, Device = 2, Copying = 3, Common sense= 4	Code	
13	Frequency of irrigation: Once a week = 1, Twice a week = 2, Thrice a week = 3, As pleased = 4	Code	
14	Method of irrigation: Furrow = 1; Hosepipe = 2, Syphon = 3	Code	

	Labour cost incurred in irrigating one acre of land considering the method of irrigation used	MK	
15	Water saving technologies in you farm: Mulching = 1, Conservation agriculture = 2; mixed cropping = 3, Composting = 4, Organic matter = 5	Code	

H: Technology Performance

Item	Issue	Unit	Answer
1	Generally. I think the tool is good for soil water monitoring: Not Applicable = 1, Strongly disagree = 2, Disagree = 3, Agree = 4, Strongly agree = 5	Code	
2	The tool does what it is supposed to do: Not Applicable = 1, Strongly disagree = 2, Disagree = 3, Agree = 4, Strongly agree = 5	Cod	
3	The tool is easy to use: Not Applicable = 1, Strongly disagree = 2, Disagree = 3, Agree = 4, Strongly agree = 5	Code	
4	The tool is the best compared to others that monitor soil water: Not Applicable = 1, Strongly disagree = 2, Disagree = 3, Agree = 4, Strongly agree = 5	Code	
5	I can recommend the tool to other farmers: Not Applicable = 1, Strongly disagree = 2, Disagree = 3, Agree = 4, Strongly agree = 5	Code	

I: Farm Inputs and Credit Accessibility

Item	Issue	Unit	Answer
1	Benefit from Farm Input Subsidy Programme (FISP): Yes = 1, No = 0	Code	
2	Credit facility availability: Yes = 1, No = 0	Code	
3	Purpose: Inputs =1; Household use = 2	Code	
4	Benefitted: Yes = 1, No = 0	Code	
5	Reasons for not benefitting: No resources for repayment = 1; Interest to high = 2; No opportunity available = 3; Other specify = 4	Code	
6	Cost of ploughing an acre of land considering the method you use	MK	

J: Extension Service Delivery

Item	Issue	Unit	Answer
1	Government support service (service delivery and follow-ups): Yes = 1, No = 0	Code	
2	Scheme meeting attendance: Yes = 1, No = 0	Code	
3	Reason for attendance: Discuss new ideas = 1, Hear reports of water allocation = 2, Attend demonstration of new ideas = 3	Code	
4	Discuss demonstration results: Yes = 1, No= 0	Code	
5	Distance: Near = 1, Reachable = 2 Far = 3	Code	
6	Value of meeting: Not of valuable = 1, Partially valuable = 2, Valuable = 3, Very Valuable = 4, Extremely valuable = 5	Code	

K: Marketing

Item	Issue	Unit	Answer
1	Crop prices are generally good: Not Applicable [5] = 1, Strongly disagree = 2, Disagree = 3, Agree = 4, Strongly agree = 5	Code	
2	Where sold (market place): Local = 1, Local vendor = 2; Co-operative =3; Other = 5	Code	
3	Prices received	MK	
4	Crops normally sold	Name	

Part II: Factors Affecting Crop Production

A: Population Effects

Item	Issue	Unit	Answer
Population Growth, Climate Change, Natural Resources Degradation and Coping Mechanisms			
1	Rainfall has decreased over the last two decades: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
2	Effects of rainfall on livelihood: Drought = 1; Mild = 2; Same = 3	Code	
3	Impact of drought: Severe = 1, Average = 2, Not Severe = 3	Code	
4	Frequency of drought: Increasing = 1, Same = 2, Reducing = 3	Code	
5	Increased over the last two decades: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
6	Availability of water for irrigation: Yes = 1; No = 0	Code	
7	Widely apparent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree=5	Code	
8	Soil fertility problems: Strongly disagree = 1, Disagree = 2, Neutral= 3, Agree = 4, Strongly agree = 5	Code	

B: Health Effects

Item	Issue	Unit	Answer
1	Population increased over the last two decades: Yes = 1, No = 0	Code	
2	Widely prevalent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
3	Immigration during the last two decades: Yes = 1, No = 0	Code	
4	Widely apparent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree=5	Code	
5	Migrated out of the area: Yes = 1, No = 0	Code	
6	Widely apparent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree=5	Code	
7	Source of domestic water: River = 1, Shallow well = 2,	Code	
8	Domestic water availability: Yes = 1, No = 0	Code	

[5] *State reason why not applicable*

9	Clean water: Yes = 1, No = 0	Code	
10	Widely apparent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree = 5	Code	
11	Has climate changed and posed uncertainties in this area? Yes=1, No=0	Code	
12	Widely apparent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree = 5		
13	Risks: Diseases = 1; Exhaustion = 2,	Code	
14	Adaptation to the potential for climate change in your farm planning? Yes=1, No=0	Code	
15	Method of adaptation: Nothing = 1, Water storage = 2, Diversification = 3, Growing of drought tolerant crops = 4	Code	

Part III: Irrigation Performance and Collective Action

A: Scheme Water Regulations and Control

Item	**Issue**	**Unit**	**Answer**
Water Use Regulations and Application			
1	Scheme fees: Yes = 1, No = 0	Code	
2	Use of fees: Canal maintenance = 1, Scheme administration = 2, Other specify = 3	Code	
3	Widely apparent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree = 5	Code	
4	Decision-makers of scheme fees: Scheme Irrigation Committee = 1, Local leadership = 2, Water committee of the WUA = 3, Other specify = 4	Code	
The Rule of Water Allocation			
5	Water allocation rule determined based on irrigated area: Yes = 1, No = 0	Code	
6	Water allocation rule determined based on crop stress: Yes = 1, No = 0	Code	
7	Decision-makers of water allocation: Scheme Irrigation Committee = 1, Local leadership = 2, Water committee of the WUA = 3, Other specify = 4	Code	
8	Water allocation rules making: Scheme Irrigation Committee = 1, Local leadership = 2, Water committee of the WUA = 3, Other specify = 4	Code	
9	What rules in making decisions about appropriation, provision, changing water allocation? Consensus or unanimity = 1, Super majority vote (2/3 majority) = 2, Simple majority vote (50% +1) = 3, Chairperson/one-man rule = 4, Scheme Irrigation committee vote = 5	Code	
10	Illegal water abstraction: Yes = 1, No = 0	Code	
11	Widely apparent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree = 5	Code	
Membership			
12	Members allowed to be voted in office: Yes=1, No=0	Code	

13	Farmers participate in water management of the irrigation: Yes = 1, No = 0	Code	
14	Widely apparent: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree = 5	Code	
15	Conflicts presence: Yes =1, N0= 0	Code	
16	Kind of conflict	Name	

B: Irrigation Information Source

Item	Issue	Unit	Answer
1	Extension service: Yes=1, No=0	Code	
2	Individual farmers or farmers' association: Yes=1, No=0	Code	
3	Media: Yes=1, No=0	Code	
4	Other government: Yes=1, No=0	Code	
5	Availability of extension messages for irrigation: Water availability or scarcity = 1, Water conservation = 2; Allocation and monitoring = 3; Conflict resolution = 4;	Code	
6	Readily available: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree = 5	Code	
7	Message appropriateness: Yes = 1, No = 2	Code	
8	Scheme meetings: No meetings = 0, Urgent and important issues =1, Regular meetings = 2, Quarterly = 3, Six times in a year = 4, Many times in a year = 5	Code	
9	Convener: Scheme management = 1; Conflicts = 2, Credit = 3, Other = 4	Code	
10	Demonstration plot availability: Yes = 1, No = 2	Code	
11	Message useful: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4 Strongly agree = 5		
12	Distance from homestead to meeting place: Near < 1 km= 1, 1 - 2 km = 2; 2 – 3 km =3, >3 km = 4	Code	
13	Attendance: Only scheme members = 1, All = 2	Code	

C: Land and Water Resources Governance

Item	Issue	Unit	Answer
Institutional Structures			
1	Control of water for irrigation: Local leadership = 1, Government = 2, Communal/Community=3	Code	
2	Land registration: Yes = 1, No = 0	Code	
3	Land policy Availability: Yes = 1, No = 0	Code	
	Relevance: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 3, Strongly agree = 4		
4	Ownership of agricultural land: Local leadership = 1; Government = 2; Private = 3	Code	
5	Frequency of irrigation facility damage: Low = 1, Medium = 2, High = 3	Code	
6	Land jurisdiction: According to scheme rules = 1. Government rules = 2, Local administration = 3	Code	

7	Appropriateness: Strongly disagree=1, Disagree=2, Neutral=3, Agree=4, Strongly agree=5		
8	Police availability: Yes = 1, No = 0		
9	Relevance: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 3, Strongly agree = 4		
Structure of Governance and Transaction Costs			
10	Water allocation for irrigation: Scheme management = 1, Block leaders = 2,	Code	
11	Performance of water allocation: Low = 1, Medium = 2, High = 3	Code	
12	Adequacy of water delivery: Low = 1, Medium = 2, High = 3	Code	
13	Reason specify:		
Smallholder Farmer Perceptions			
14	Ownership of irrigation scheme: The government = 1, Local leadership = 2, Private owners = 3 Farmers = 4,	Code	
15	Land ownership: The government = 1, Local leadership = 2, Private owners = 3 Farmers = 4,	Code	
16	Reason specify		

D: Criteria for Evaluation

Item	Question	Unit	Answer
Scheme Water Delivery Use Efficiency			
1	Efficiency of water distribution: Not efficient = 1, Efficient =2, Very efficient = 3	Code	
2	Rate: Strongly disagree=1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
3	Fairness or equity: Rule of differential ability to contribute = 1; The principle of equality between individuals' contributions to an effort and the benefits they derive/farmers must pay according to the level of benefits/water use=2	Code	
4	Land Policy adequacy: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
5	Land Policy meeting smallholder farmer's aspirations: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
6	Irrigation Policy adequacy: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
7	Irrigation Policy meeting smallholder farmer's aspirations: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
Accountability			
8	Corruption by irrigation committee members: Removed outright = 1, Be heard = 2, Convicted and imprisoned= 3	Code	
9	Decision of 8: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	

10	Legitimacy of irrigation committee members: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
Election Process Based on Values of Local Actors			
11	Corrupt leaders voted into office: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
12	Trustworthy leaders who keep promises and help farmers can be voted into office: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	

E: Behaviour and Attitude of Irrigation Scheme Committee towards Water Management

Item	Issue	Unit	Answer
1	Personality factors: Openness to new experiences = 1, Extraversion = 2, Agreeableness = 3, Neuroticism = 4, Conscientiousness = 5	Code	
2	Resistance to change (Openness): Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
3	Satisfied with the management of water resources: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
4	Scheme fees process for collection easy and essential: Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
5	Water allocation fairness and adequacy Strongly disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly agree = 5	Code	
6	Water allocation conflicts: Yes = 1, No = 0	Code	
7	Prevalence: Often = 1, Haphazard = 2, Seized = 3	Code	
8	Observation; Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
9	Scheme and field canals timely maintained: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
10	Management transparency: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	

Part IV: Attributes of Irrigated Agricultural System

Item.	Issue	Unit	Answer
	Storage Facility		
1	Granary storing crops: Yes =1, No = 0	Code	
2	Water storage facility: Yes=1, No=0	Code	
3	Type of Facility: None = 0, Tank = 1, Dam = 2,	Code	
4	Market availability: Yes = 1, No = 2		
5	Cooperative association availability: Yes = 1, No = 2		
Facility Rehabilitation:			
6	Condition of facility: Worse = 1, Bad = 2, Good = 3, Very Good = 4	Code	

7	Requirement of rehabilitation: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
8	Degree of water problems; Very severe = 1, Severe = 2, Not Severe = 3, Just adequate = 4	Code	
9	Need of rehabilitation: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
10	Beneficial to rehabilitate: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
11	Involvement: Yes =1, No = 0	Code	
12	Plan: Contribution of labour = 1, Contribution of financial resources = 2, Contribution by government = 3, Contribution by private sector = 4	Code	
13	Reliability of water source: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
14	Predictability of rainfall: Predictable=1, Erratic=0	Code	
15	Challenges to water control: Yes = 1, No = 0	Code	
16	Prevalent: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	

A: Attributes of smallholder actions to water allocation

Item.	**Issue**	**Unit**	**Answer**
Field Water Allocation			
1	Basis of water distribution: According to crops = 1, According to soil type = 2, According to land size= 3,	Code	
2	Observation: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
3	Farmer depends on irrigation for a major portion of household income/livelihood: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
Common Understanding			
4	Smallholder farmers have similar views on strategies of water use: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
5	Smallholder farmers have similar views on strategies of provision of materials, labour, and money: I strongly disagree=1, I disagree=2, Neutral=3, I agree=4, I strongly agree=5	Code	
6	Same penalty muted to offenders of similar offence: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
6	Importance of irrigation to household income and food security: very important = 1; important and Necessary = 2; Not Important	Code	
8	Observation: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5		
9	Contribution of irrigated agriculture to household income: <25%=1, 25-50%=2, 50-75%=3, > 75%=4,	Code	
10	Universality of challenges: Common = 1; Not common = 2	Code	

11	Poor farmers affected greatly: yes = 1, No = 2		
12	Observation: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5		
13	Smallholder farmers trust one another and keep promises/agreements on water use: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
14	Changes to the rules in water use and irrigation management: Yes = 1, No = 0,	Code	
15	If Yes: how long	Numb	
Social Capital			
16	Member of any environmental or conservation group: Yes =1, No = 0	Code	
17	Member of any social group: Yes=1, No=0	Code	
18	Position: Yes = 1, No = 0, Ordinary member = 3	Code	
19	If Yes: Chairman = 1, Vice Chair = 2, Secretary = 3, Vice Secretary = 4, Treasurer = 5	Code	
20	Scheme meeting attendance: Yes = 1, No = 0	Code	
21	Interaction with others: Yes = 1, No = 0	Code	
22	Interaction reason	Name	

B: Factors influencing farmer participation in using simple irrigation monitoring tools

Item	Issue	Unit	Answer
1	Taking all things together, how happy are you; would you say you are very happy =1, happy =2, not very happy =3, not at all happy = 4, Sad = 5	Code	
2	Satisfaction with your life as a whole these days: Completely Dissatisfied =1; Dissatisfied = 2; Satisfies = 3; Very Satisfied = 4; Completely Satisfied = 5	Code	
3	Opinion about water use and nutrient conservation which is important between the two: Water = 1; Nutrient conservation = 2	Code	
4	Please tell me whether you agree or disagree with the following statement: Water use is very important in irrigation: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
5	Learning is important how to use simple irrigation: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
6	Usefulness of the learning about SIMT: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
7	The ease of the use of the SIMT-learning system: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
8	Next, please tell me if you strongly agree, agree, disagree, or strongly disagree: is it acceptable to use SIMT: Strongly	Code	

	disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5		
9	Overall perception, SIMT will improve household livelihoods: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
10	Do you think education is important in using SIMT: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
11	Which of the following statements comes closer to your sentiment on the use of SIMT: Feel constrained by the rules that exist in the scheme =1, There are no avenues to guide the use of tools = 2; The environment is conducive to learning and guidance on SIMT usage	Code	
12	Any member of the scheme can participate in SIMT: Yes=1, No=0	Code	
13	If no, what are the reasons: specify:		

C: Attitude towards Farmer-Learning

Item	Issue	Code	Answer
1	If available, I intend to learn and use the tool during the season: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
2	If cheaply available, I intend to use tools as frequently as possible: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
3	If available, I intend to use e-learning tools whenever possible for my coursework: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
4	I believe it will be a good idea to use a tool: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
5	Participation in irrigation learning has a positive effect on behavioural intention to continuously use tools: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
6	Support provision to learning how to use tool: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
Technology Acceptance			
7	Improves farming practices: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
8	Increases agricultural productivity: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
9	Learning about technology can be as rewarding as the technology itself: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
10	Do other farmers come for advice on the new technologies: Yes = 1, No =0	Code	

Social Influence (SI)			
11	Fellow farmers influence my behaviour to learn and use SIMT: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
12	People who are important to me think that I should use SIMT: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
13	Irrigation scheme management has been helpful in the use of SIMT: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
14	Interaction with other farmers based on SIMT is clear and understandable: Strongly disagree = 1, Disagree = 2, Neural = 3, Agree = 4, Strongly agree = 5	Code	
15	Perceived SIMT usefulness: Extremely useful = 1, Very useful = 2, Useful = 3, Not Useful = 4, Completely Useless	Code	
16	Participation by a household member in scheme and block meetings and training of irrigation water management: Never=0, Rarely=1, Sometimes=2, Always=3	Code	
17	Do you get any supplementary income in addition to income from agriculture: Yes = 1, No =0	Code	
18	Remittances: Out-migrants = 1, Government pensions = 2	Code	
19	Local leadership role: Yes = 1, No = 0	Code	
20	Irrigation time in one rotation?	Numb	
21	Use of groundwater: Yes =1, No = 0	Code	
22	Effects of using SIMT: Improved water use = 1; Improved crop yield = 2, Labour availability = 3, Improved status = 4	Code	
23	Recommend to others: Yes, No = 2		
24	Did you ever participate in planning and designing the irrigation system: Yes = 1, No = 0	Code	
25	Are water resource management practices adequate? Yes = 1, No = 0	Code	
26	Do you implement all water management practices as advised? Yes = 1, No = 0	Code	
27	If Yes, <25% = 1, 25 – 50% =2, 50 – 75% = 3, >75% = 4	Code	
28	Do you participate in meetings called by Block leadership and Irrigation Scheme Management Authorities? Never = 0, Sometimes = 1, Always = 2	Code	
29	Do you consult any of the WUA or irrigation office personnel about your problems? Never = 0, Sometimes = 1, Always = 2	Code	
30	Do you share any information or experience that you have about water resources with other farmers? Never = 0, Sometimes= 1, Always = 2	Code	
31	Do you share any information or experience that you have about the water resource with any Irrigation Scheme Management? Never = 0, Sometimes = 1, Always = 2	Code	
32	Do you consult your fellow farmers about your problems? Never = 0, Sometimes = 1, Always = 2	Code	

33	Do you attend water management training organised by Irrigation Scheme management? Never = 0, Sometimes = 1, Always = 2	Code	
34	Do you contribute anything towards any construction on the scheme? Never = 0, Sometimes = 1, Always = 2	Code	
35	Do you contribute anything towards the maintenance of irrigation structures on the schemer? Never = 0, Sometimes= 1, Always = 2	Code	
36	Do you contribute labour towards any construction of some conservation structures on irrigation water? Never= 0, Sometimes= 1, Always = 2	Code	
37	Do you contribute any labour towards repairs and maintenance of any conservation structures on irrigation water? Never = 0, Sometimes= 2, Always = 2	Code	
38	Ownership of the land: Yes = 1, No = 0	Code	
39	Size of land under irrigation	Ha	
40	Land location on scheme: Bottom = 1, Low = 2, Middle = 3, Upper = 4, Top = 5	Code	
41	Land location on canal network: Tail-end=1, Middle=2, Head=3	Code	
42	Irrigation water availability: Yes = 1, No = 0	Code	
43	Adequate irrigation water is available: Yes = 1, No = 0	Code	
44	Irrigation water is available on an equity basis: Yes = 1, No = 0	Code	

This is the end of the interview and once again I would like to thank you for your time to participate in this research and appreciate very much all your contributions to the questions and issues asked!

UNICAF UNIVERSITY

Appendix C: Reaf Form

UNICAF UNIVERSITY RESEARCH ETHICS APPLICATION FORM DOCTORAL STUDIES	UREC USE ONLY: Application No: Date Received:

Student's Name: Elisha Gerry Jostone Vitsitsi

Student's E-mail Address: gvitsitsi@yahoo.com

Student's ID #: R1802D4533932

Supervisor's Name: Dr Ursula Schinzel

University Campus: Unicaf University Zambia (UUZ)

Program of Study: UUZ: PhD Doctorate of Philosophy

Research Project Title: Assessing Water Productivity and Profitability through Farmer Learning in Selected Smallholder Irrigation Schemes in Malawi

1. **Please state the timelines involved in the proposed research project:**

Estimated Start Date: 22-Aug-2021 Estimated End Date: 2-Oct-2021

2. **External Research Funding (if applicable):**

2.a. Do you have any external funding for your research?

☐ YES ☒ NO

If YES, please answer questions **2b** and **2c**.

2.b. List any external (third party) sources of funding you plan to utilise for your project. You need to include full details on the source of funds (e.g. state, private or individual sponsor), any prior / existing or future relationships between the funding body / sponsor and any of the principal investigator(s) or co-investigator(s) or student researcher(s), status and timeline of the application and any conditions attached.

2.c. If there are any perceived ethical issues or potential conflicts of interest arising from applying or and receiving external funding for the proposed research then these need to be fully disclosed below and also further elaborated on, in the relevant sections on ethical considerations later on in this form.

3. The research project

3.a. Project Summary:

In this section fully describe the purpose and underlying rationale for the proposed research project. Ensure that you pose the research questions to be examined, state the hypotheses, and discuss the expected results of your research and their potential.
It is important in your description to use plain language so it can be understood by all members of the UREC, especially those who are not necessarily experts in the particular discipline. To that effect ensure that you fully explain / define any technical terms or discipline-specific terminology (use the space provided in the box).

Sufficient water application to benefit good crop growth is based on trial and error among most smallholders irrigation schemes globally. Farmer learning employing user-friendly soil water and nutrient monitoring devices are being promoted in Malawi to enhance and increase productivity particularly smallholder farmers. The main purpose is to water productivity and profitability through farmer learning in selected smallholder irrigation schemes in the Central and Southern Regions of Malawi. A modest device known as a chameleon was designed to allow illiterate smallholders in Africa to provide a result linked to when and how much water to apply on a farmer's plot. And also water front detectors to show water movement in the soil. 60 farmers have been given the devices in three irrigation schemes. A total of 162 farmers will be interviewed comprising 18 farmers in each irrigation scheme using these devices with a corresponding number of farmers not using these devices but from the same schemes and 18 farmers from nearby irrigation schemes as a control. The device demonstrates information on soil moisture condition by colours: blue, green and red colours representing sufficient, moderate and dry soil moisture condition, respectively.

The use of colours and not numbers encourage and stimulate illiterate farmers to know when and how water much to use, whereas, waterfront detectors capture water that contains nutrient leaching as water percolates through the soil climaxing in learning by doing thereby getting strong water management perception. The study purpose is to intensify and appreciate how social learning theory can be applied to enhance water use efficiency and irrigated farming practices. The expected results are to provide farmers with new ideas of water management by increasing water use efficiency; indicating time and reducing labour for water application.

3.b. Significance of the Proposed Research Study and Potential Benefits:

Outline the potential significance and/or benefits of the research (use the space provided in the box).

The significance of the study is about reduction of water application, labour and saving of time for other chores. Water use reduction on farmers' plots will also decrease soil nutrient losses so that crops can grow well consequently improving productivity. Innovative irrigation ideas and efforts can increase water use efficiency, attaining profitable benefits while also decreasing environmental challenges. Since water is becoming a scarce commodity, reducing water application through utilising innovative devices can improve rapport; reduce tensions and conflicts among the farmers. These farmers ordinarily lack suitable means and inducements to appreciate crops' water use, realistic water applications and productivity concerning diverse water management practices, and hence low water-efficiency levels. This research intends to assess the social learning role for irrigation development in Malawi. The proposition is that social learning detects an overall swing from talking to doing,

4. <u>Project execution:</u>

4.a. The following study is an:

[x] experimental study (primary research)

[ ] desktop study (secondary research)

[ ] desktop study using existing databases involving information of human/animal subjects

[ ] Other

If you have chosen 'Other' please Explain:

4.b. Methods. The following study will involve the use of:

Method	Materials / Tools
Qualitative:	[x] Face to Face Interviews Phone [ ] Interviews [ ] Face to Face Focus Groups [ ] Online Focus Groups [ ] Other *
Quantitative:	[ ] Face to Face Questionnaires [ ] Online Questionnaires [ ] Experiments [x] Tests [ ] Other *

*If you have chosen 'Other' please Explain:

Face-to-Face interviews is a data collection method used directly by the researcher interacting with a respondent according to a prepared questionnaire (attached). This method certifies the quality of acquired data and intensifies the response rate. Focus group discussion is commonly used to get in-depth views of social issues, whose aim is to get data from purposely chosen persons rather than from a statistically sampled group of a larger population using a questionnaire (attached). An observation checklist is a list of things that a researcher looks at during

5. <u>Participants:</u>

5 a. Does the Project involve the recruitment and participation of additional persons other than the researcher(s) themselves?

[ ] YES NO

[x]

If YES, please complete all following sections.

If NO, please directly proceed to Question 7.

5 b. Relevant Details of the Participants of the Proposed Research

State the number of participants you plan to recruit, and explain in the box below how the total number was calculated.

Number of participants 162

In Malawi the age of 18 years is considered as an adult and some of this group are found on smallholder schemes farming due to death of their parents and other circumstances and look after their sibling

Describe important characteristics such as: demographics (e.g. age, gender, location, affiliation, level of fitness, intellectual ability etc). It is also important that you specify any inclusion and exclusion criteria that will be applied (e.g. eligibility criteria for participants).

Age range From 18 To 65

Gender ☒ Female

☒ Male

Eligibility Criteria:

- Inclusion criteria

In Malawi the age of 18 years is considered as an adult and some of this group are found on smallholder schemes farming due to

- Exclusion criteria

Those farmers that are not included and do have plots on irrigation schemes will not participate and probably those who are

Disabilities

Only farmers aged 18 years and above will be interviewed and those providing informed consent shall be chosen and not with mental disabilities.

Other relevant information (use the space provided in the box):

5 c. Participation & Research setting:

Clearly describe which group of participants is completing/participating in the material(s)/tool(s) described in 5b above

The first 54 (18 each) farmers chosen group by scheme management using soil water and nutrient monitoring tools will complete Farmers' Learning Record Book recording water application rate and rate. Second group of 54 (18 each) farmers selected purposively from a scheme's sample frame not using the tools but based on attendance frequency and their keen interest in imitating what their first group is doing. Third group of 54 (18 each) farmers chosen randomly

(use the space provided in the box).

5 d. Recruitment Process for Human Research Participants:

Clearly describe how the potential participants will be identified, approached and recruited (use the space provided in the box).

Several issues that favour effective participants' recruitment should: One, the research be based on a long-standing partnership among the researcher, a large irrigated farming community as well as academia. Two, the researcher had created recruitment approaches with related groups that proved successful in previous studies. Three, he requested help from the Department of Irrigation for the research study to be conducted to assess the potential use of the soil water and nutrient monitoring tools by farmers in smallholder irrigation schemes. Potential participants who shall be identified, approached and recruited shall be based on a concept of shared benefits.

5 e. Research Participants Informed Consent.

Select below which categories of participants will participate in the study. Complete the relevant Informed Consent form and submit it along with the REAF form.

Yes	No	Categories of participants	Form to be completed
☑	☐	Typically Developing population(s) above the maturity age *	Informed Consent Form
☐	☑	Typically Developing population(s) under the maturity age *	Guardian Informed Consent Form

* Maturity age is defined by national regulations in laws of the country in which the research is being conducted.

5 f. Relationship between the principal investigator and participants.

Is there any relationship between the principal investigator (student), co-investigators(s), (supervisor) and participant(s)? For example, if you are conducting research in a school environment on students in your classroom (e.g. instructor-student).

☐ YES ☒ NO

If YES, specify (use the space provided in the box).

6. Potential Risks of the Proposed Research Study.

6 a. i. Are there any potential risks, psychological harm and/or ethical issues associated with the proposed research study, other than risks pertaining to everyday life events (such as the risk of an accident when travelling to a remote location for data collection)?

☐ YES ☐ NO

If YES, specify below and answer the question 6 a.ii.

6 a.ii Provide information on what measures will be taken in order to exclude or minimise risks described in 6.a.i.

By assembling a research team with the necessary capability and experience to conduct this type of research, is possible to minimise risks. Risks to research participants can be reduced by using processes and measures that are consistent with robust research design and that do not unreasonably expose participants to risk, wherever and whenever applicable and also using appropriate measures. These may include changing prescreening of participants to find and exclude high-risk participants, and providing as much information

6 b. Choose the appropriate option

		Yes	No
i.	Will you obtain written informed consent form from all participants?	√	
ii.	Does the research involve as participants, people whose ability to give free and informed consent is in question?		√
iii.	Does this research involve participants who are children under maturity age? If you answered YES to question iii, complete all following questions. If you answered NO to question iii, do not answer Questions iv, v, vi and proceed to Questions vii, viii, ix and x.		√
iv.	Will the research tools be implemented in a professional educational setting in the presence of other adults (i.e. classroom in the presence of a teacher)?		√
v.	Will informed consent be obtained from the legal guardians (i. e. parents) of children?		√
vi.	Will verbal assent be obtained from children?		√
vii.	Will all data be treated as confidential? If NO, explain why confidentiality of the collected data is not appropriate for this proposed research project, providing details of how all participants will be informed of the fact that any data which they will provide will not be confidential.	√	

viii.	Will all participants /data collected be anonymous? If NO, explain why and describe the procedures to be used to ensure the anonymity of participants and/or confidentiality of the collected data both during the conduct of the research and in the subsequent release of its findings.	√	☐
ix.	Have you ensured that personal data and research data collected from participants will be securely stored for five years?	√	☐
x.	Does this research involve the deception of participants? If YES, describe the nature and extent of the deception involved. Explain how and when the deception will be revealed, and who will administer this debrief to the participants:	☐	√

6 c. i. Are there any other ethical issues associated with the proposed research study that are not already adequately covered in the preceding sections?

☐ Yes ☐ No

If YES, specify (maximum 150 words).

6 c. ii Provide information on what measures will be taken in order to exclude or minimise ethical issues described in 6.c.i.

All participants to be interviewed shall provide their informed consent before interviewing them and a copy will be attached. Secondly, they shall be informed to be free to participate or leave if they feel uncomfortable with the questions. Thirdly, since participants protection is vital, the environment in which interviews will be conducted shall be secure, and lastly, the information will be treated confidentially and stored in a very secure place.

6 d. Indicate the Risk Rating.

High ☐ ☐ Low

7. Further Approvals

Are there any other approvals required (in addition to ethics clearance from UREC) in order to carry out the proposed research study?

☐ YES √ NO

If YES, specify (maximum 100 words).

8. Application Checklist

Mark √ if the study involves any of the following:

☐ Children and young people under 18 years of age, vulnerable population such as children with special educational needs (SEN), racial or ethnic minorities, socioeconomically disadvantaged, pregnant women, elderly, malnourished people, and ill people.

☐ Research that foresees risks and disadvantages that would affect any participant of the study such as anxiety, stress, pain or physical discomfort, harm risk (which is more than is expected from everyday life) or any other act that participants might believe is detrimental to their wellbeing and / or has the potential to / will infringe on their human rights / fundamental rights.

☐ Risk to the well-being and personal safety of the researcher.

☐ Administration of any substance (food / drink / chemicals / pharmaceuticals / supplements / chemical agent or vaccines or other substances (including vitamins or food substances) to human participants.

☐ Results that may have an adverse impact on the natural or built environment.

9. Further documents

Check that the following documents are attached to your application:

		ATTACHED	NOT APPLICABLE
1	Recruitment advertisement (if any)	☐	☐ ▯
2	Informed Consent Form / Guardian Informed Consent Form	☐	☐ ▯
3	Research Tool(s)	▯	☐

4	Gatekeeper Letter	☐	☐ ▯
5	Any other approvals required in order to carry out the proposed research study, e.g., institutional permission (e.g. school principal or company director) or approval from a local ethics or professional regulatory body.	☐	☐ ▯

10. Final Declaration by Applicants:

(a) I declare that this application is submitted on the basis that the information it contains is confidential and will only be used by Unicaf University for the explicit purpose of ethical review and monitoring of the conduct of the research proposed project as described in the preceding pages.

(b) I understand that this information will not be used for any other purpose without my prior consent, excluding use intended to satisfy reporting requirements to relevant regulatory bodies.

(c) The information in this form, together with any accompanying information, is complete and correct to the best of my knowledge and belief and I take full responsibility for it.

(d) I undertake to abide by the highest possible international ethical standards governing the Code of Practice for Research Involving Human Participants, as published by the UN WHO Research Ethics Review Committee (ERC) on http://www.who.int/ethics/research/en/ and to which Unicaf University aspires to.

(e) In addition to respect any and all relevant professional bodies' codes of conduct and/or ethical guidelines, where applicable, while in pursuit of this research project.

Student's N Elisha Gerry Jostone Vitsitsi

Supervisor's Name: Dr Ursula Schinzel

Date of Application: 12-Aug-2021

☐ **I agree with all points listed under Question 10**

Important Note:

Save your completed form (we suggest you also print a copy for your records) and then submit it to your UU Dissertation/project supervisor (tutor). **In the case of student projects, the responsibility lies with the Faculty Dissertation/Project Supervisor.** If this is a student application, then it should be submitted via the relevant link in the VLE. Please submit only electronically filled in copies; **do not** hand fill and submit scanned paper copies of this application.

Appendix D: Informed Consent Form Part 2: Signed Certificate of Consent

UNICAF UNIVERSITY

InformedConsentForm

Part1:DebriefingofParticipants

Student'sName: ElishaVitsitsi

Student'sE-mailAddress: gvitsitsi@yahoo.com

StudentID#: R1802D4533932

Supervisor'sName: DrUrsulaSchinzel

UniversityCampus: Unicaf University Zambia (UUZ)

Program of Study: UUZ:PhDDoctorateofPhilosophy

ResearchProjectTitle: AssessingWaterProductivityandProfitabilitythroughFarmerLearning in Selected Smallholder Irrigation Schemes in Malawi.

Date: 06-Feb-2021

Provideashortdescription(purpose,aimandsignificance)oftheresearchproject,and explain why and how you have chosen this person to participate in this research (maximum 150 words).

The purpose of this research study is to assess water productivity and profitability through farmer learning and identify social learning methods in selected smallholder irrigation schemes in Malawi andtheircontributionto theacceptance,adoption,diffusionandwateruseefficiencytechnologies. Water use efficiency(WUE) is a vital key in water resources managementas well as climate change researchandhydrologicalstudies,as it displayshowcarbonandwatercyclesarecombined.WUE is an important and effective integral trait for assessing the responses of agricultural ecosystems to climate change particularly water scarcity. Briefly, WUE is described as the carbon amount assimilated by crops produced per unit of water consumed. Notably, climate change affects crop growth, however opportunities to enhance WUE through user-friendly technologies to offset the impact of a changing climate and water scarcity are currently available requiring users (farmers) to learn how they operate.

The above named Student is committed in ensuring participant's voluntarily participation in the research project and guaranteeing the;pre are no potential risks and/or harms to the participants.

Participantshavetherighttowithdrawatanystage(priororpostthecompletion)ofthe research without any consequences and without providing any explanation. In these cases, data collected will be deleted.

Alldataandinformationcollectedwillbecodedandwillnotbeaccessibletoanyoneoutside this research. Data described and included in dissemination activities will only refer to coded information ensuring beyond the bounds of possibility participant identification.

I, ElishaVitsitsi **ensure that all informationstatedabove istrueandthatallconditionshavebeenmet.**

Student'sSignature: [signature]

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UNICAF UNIVERSITY

Informed Consent Form

Part 2: Certificate of Consent

This section is mandatory and should to be signed by the participant(s)

Student's Name: Elisha Vitsitsi

Student's E-mail Address: gvitsitsi@yahoo.com

Student ID #: R1802D4533932

Supervisor's Name: Dr Ursula Schinzel

University Campus: Unicaf University Zambia (UUZ)

Program of Study: UUZ: PhD Doctorate of Philosophy

Research Project Title: Assessing Water Productivity and Profitability through Farmer Learning in Selected Smallholder Irrigation Schemes in Malawi.

12:28:31 pm

I have read the foregoing information about this study, or it has been read to me. I have had the opportunity to ask questions and discuss about it. I have received satisfactory answers to all my questions and I have received enough information about this study. I understand that I am free to withdraw from this study at any time without giving a reason for withdrawing and without negative consequences. I consent to the use of multimedia (e.g. audio recordings, video recordings) for the purposes of my participation to this study. I understand that my data will remain anonymous and confidential, unless stated otherwise. I consent voluntarily to be a participant in this study. HID:21 23/5/21

Participant's Print name: Agather Chawanda

Participant's Signature: ______________

Date:

If the Participant is illiterate:

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had an opportunity to ask questions. I confirm that the aforementioned individual has given consent freely.

Witness's Print name: McDONALD CHIKHAWA

Witness's Signature: [signature]

Date: 23/05/21

2

Appendix D: Record Book for User-Friendly Soil Water and Nutrient Monitoring Tool Farmers

Farmer Code: .... **Date: ....**

Water and Solute Monitoring Record Book

District	
Traditional Authority	
Village	
Name of Irrigation Scheme	
Block Number	
Plot Number	
Extension Planning Area	

Farmer information

Name		
Gender	Male/Female (M/F)	
Position	Head	
	Spouse	
	Son	
	Daughter	
	Nephew	
	Niece	
	Maid	

Land resources

Landholding			**Rent**
Total hectares			
Where	Dryland		
	Wetland		

Cropping information

Crop type	**Area**		**Planting spacing**		**Planting density**	
	Size	**Unit**	**Inter row**	**Intra row**	**Planting date**	**Harvest date**

Financial Input

Input type	**Unit**	**Quantity**	**Cost**	**Total cost**	**Date(s)**
Seed					
Fertiliser					
Basal dressing					
Top dressing					
Organic fertiliser (manure)					
Other chemicals					
Pesticide					
Herbicide					

Cost of family labour

Input type	Quantity	Unit	Cost	Total cost
Field preparation				
Seedbed levelling				
planting				
Irrigation				
Treadle pump				
Motorised pump				
Fertilising				
Harvesting				
Total				

Cost of hired labour

Input type	Quantity	Unit	Cost	Total cost
Weeding				
Fertilising				
Transport				
Harvest				
Transport				
Total				

Remarks

Irrigation Scheduling and Chemical Application

Date	Irrigated	Rained[6]	Chameleon colour			WFD readings at 20 cm			WFD readings at 40 cm			Remarks[7]
	Yes/No	(mm)	15 cm	30 cm	45 cm	up/down	EC (mS)	NO_3 (mg/l)	up/down	EC (mS)	NO_3 (mg/l)	

[6] Rainfall event (quantity from rain gauge)

[7] (I) Crop condition (Likert rating: 1 = bad crop; 2 = below average; 3 = average crop; 4 = good crop; 5 = very good crop

(ii) Plant development stage

(iii) Duration of irrigation in hours

Date	Irrigated	Rained[8]	Chameleon colour			WFD readings at 20 cm			WFD readings at 40 cm			
	Yes/No	(mm)	15 cm	30 cm	45 cm	up/down	EC (mS)	NO_3 (mg/l)	up/down	EC (mS)	NO_3 (mg/l)	Remarks[9]

[8] *Rainfall event (quantity from rain gauge)*

[9] *(I) Crop condition (Likert rating: 1 = bad crop; 2 = below average; 3 = average crop; 4 = good crop; 5 = very good crop*

(ii) Plant development stage

(iii) Duration of irrigation in hours

Date	Irrigated	Rained[10]	Chameleon colour			WFD readings at 20 cm			WFD readings at 20 cm			Remarks[11]
	Yes/No	(mm)	15 cm	30 cm	45 cm	up/down	EC (mS)	NO_3 (mg/l)	up/down	EC (mS)	NO_3 (mg/l)	

[10] *Rainfall event (quantity from rain gauge)*

[11] *(I) Crop condition (Likert rating: 1 = bad crop; 2 = below average; 3 = average crop; 4 = good crop; 5 = very good crop*

(ii) Plant development stage

(iii) Duration of irrigation in hours

Yield, marketing and income information

Crop	Total Yield		Consumed		Sold		Income sales		Market location[12]
	Quantity	Unit	Quantity	Unit	Quantity	Unit	Cost/unit	Total cost	

Other (specify):

[12] *1 = Local; 2 = District; 3 = Town; Other specify*

Management schedule and planning

Week 1:

Plan for the week based on Chameleon reading, rainfall, crop choice and rationality:

Week 2:

1. Discuss planned management actions against actual actions, identify differences and provide reasons triggering the actions:

2. Discuss the reading from the Chameleon mean regarding irrigation and what lessons were learnt:

3. Discuss management actions and plans for the coming week and prudence based on the device readings, crop growth, vigour and other observations

4. Check any similarity in device readings and actions taken and identify any patterns and actions taken. Provide what lessons learnt are beneficial to the household

5. Provide any discussions done with any farmers within and outside the scheme. Any visitors who came to me to see what was done and any comments made by the visitors:

General discussions

Discussions at the scheme level, what lessons have the scheme management learnt regarding the use of User-Friendly Soil water and Nutrient Monitoring Tool?

Harvest

Discuss family food availability and household income.

Post-harvest

1. Discuss with other farmers what happened during the season in the light of the final harvest and what would or should they have done differently.

2. What will you, as the Scheme, do differently next season based on what you have learnt from the last season?

Appendix E: Focus Group Guide

A. Introduction and Instructions to the Survey Participants

Welcome Remarks

I thank you for accepting to take part in this focus group discussion that intends to look at assessing water productivity and profitability through farmer learning in the irrigation scheme. Your participation is of particular importance to change how water resources have been misused and farmers not benefiting much due to inappropriate water application. I do appreciate that you are busy people and your time is very valuable.

Introduction:

This focus group discussion forms part of my Doctor of Philosophy degree requirement at Unicaf University in Zambia and my interest in establishing your feelings about how irrigation activities are performed and what socio-economic issues influence the use of these novel tools introduced in the scheme. The discussion will take no more than one and a half hours so that you may go and do other equally important duties.

Anonymity

This discussion is taken to be confidential and anonymous meaning that there is no need to give me your names. The transcribed notes will not contain information that would expose individual responses to be linked to some specific statements. Please try to answer and comment as accurately and truthfully as possible on the question asked. I would like to emphasise that refrain from discussing the comments of other group members outside this focus group discussion time. If there are any questions and/or discussions you feel uncomfortable with, please do not answer or participate; nonetheless, you may try to answer some and be as involved as possible to make this discussion fruitful.

B. Introductory questions

When was this irrigation scheme established? ____
How many members are in the scheme? __________________M________________F ________
How was the group started? ____
Why instigated the formation of the irrigation scheme? _______________________________
What activities are you involved in ____
____
____

C. Focus Group Discussion Guide

1. How would you describe the farmers' attitudes towards irrigation (What did people think/say/do?)
   ____
   ____
   ____

2. What influences the positive and/or negative reactions of farmers to the scheme's irrigation activities?
   ____
   ____
   ____

3. What are the technologies you have been exposed to that have benefitted farmers in the scheme? You may rank them.

   (i)
   (ii)
   (iii)
   (iv)

4. For each of the technologies ranked above or earlier prioritized?

   a) What do you like most about it? ____
   ____
   ____

   b) What do you like least? ____
   ____
   ____
   ____

   c) What are the main factors hindering adoption by more farmers? __________________
   ____

____

____

D. Socioeconomic characterisation

5. What types of farmers are mostly adopting irrigation technologies (by gender, age, wealth, land ownership).

____

____

____

6. What are the most important resources required to adopt irrigation technology (i.e. labour, land, capital, and water)? ____

____

____

____

7. Was there any affinity to share the technology(ies) with colleagues in the scheme? (Yes/No)

____

____

____

8. If so, who inclines to share the technology most with whom, and for what reasons?_____

____

____

____

9. Does this vary by the type of technology Yes/No; if yes why?______________________

____

____

____

10. Among the farmers, you may have observed and noticed, what have been the most useful changes made to how water is used? ____

____

____

____

11. How has it changed and why? ____

____

____

____

12. How did the user-friendly soil water and nutrient monitoring tools appear in the scheme to enable their use?____

13. Has the introduction of the tools benefitted farmers and are there any impacts on farmers' livelihoods or the community at large? Please indicate BOTH positives and negatives if any.

14. What are the most cultivated crops (rank)? ________________________________
    (i)
    (ii)
    (iii)
    (iv)

15. Does membership in a group or association or cooperative help in irrigation technology adoption? Yes/No____

16. Explain your response ____

17. How often have you observed farmer meetings being conducted to discuss how climate change is affecting water availability generally? ______________________________

    (a) Weekly ____
    (b) Fortnightly____
    (c) Monthly ____
    (d) Once a year ____
    (e) Any other: Please specify ___________________________________

E. Administrative environment

18. What are the main sources of agricultural information?
    (a) Radio
    (b) Newspaper
    (c) Internet
    (d) Government
    (e) CBOs/FBOs/NGOs/CSOs
    (f) Other

19. Do you receive any support from outside? Yes/No; If yes specify

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____

20. In your opinion, what do you think should be done to increase the number of tools in the irrigation scheme?

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____

21. Of all the issues discussed, what are the most important that you would like to mention regarding the introduced technology in the scheme? ______________________

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Thank you for participating. This has been a very successful discussion for improving crop production and saving water on irrigation schemes.