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The role of Conservation Agriculture in improving smallholder farmers' crop yields in Malawi

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MSc International Relations

DECLARATION

I hereby declare that this thesis is a product of my original work. All sources of information other than my own have been acknowledged and referenced. This study has not been submitted and will not be submitted for any other degree in any other University or award.

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DEDICATION

I would dedicate this thesis to my parents and my siblings.

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I profoundly express my gratitude to The Most High, God the Creator, for the blessings of life and for seeing me through this thesis, without whom the thesis would not have been a success. I am forever grateful.

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Ndinotenda Mwari. Hallelujah!

Table of Contents

List of Tables

List of Figures

Abstract

Land degradation and climate change through unreliable rainfall regimes, extreme temperatures, floods, and so on have posed a severe menace to food security and natural resource management in Malawi and sub-Saharan Africa. The principal objective of this study was to investigate the impact of Conservation Agriculture (CA)-associated technologies on smallholder farmers' crop yields. The other objectives of this study were to review the impact on smallholders' income and, finally, the role of livestock in improving the economics and income of the smallholder farmers in the Dowa district in Malawi. The study data was collected from October 2021 to November 2021 using KoBo Toolbox[1] *Software. Subsequently, the data were subjected to analysis through cross-tabulation and contingency tables to determine the effect of CA technologies on crop yields of maize, beans, soybeans, vegetables, sweet potatoes, Irish potatoes, and groundnuts.*

The study used SPSS[2] *analysis software to determine the impact of mulching, zero tillage, and cropping systems (mixed cropping, intercropping, and monocropping) on crop yields in the Dowa district in Malawi. In addition, the study analysed the impact of CA on income and the importance of livestock in boosting smallholder farmers' income and smallholders' finances. From the descriptive statistics, many smallholder farmers (52) in Dowa used buckets for irrigation. The most prevalent way smallholders sell agricultural produce was through a vendor/middlemen. Agriculture is the backbone of most households in this study, with crop production and the sale of farm products rated as the most crucial source of livelihood by the respondents.*

The study further found that crop yields of soybeans, beans, maize, Irish potato, and sweet potatoes increased for those who practiced mulching while groundnuts and vegetables decreased. Groundnuts, soybeans, maize, Irish potato, and vegetables performed well, almost doubling the yields of those who did not practice the technology when zero tillage was applied. In addition, more yields were realized from mixed cropping and intercropping systems compared to monocropping. However, in this study, the yield difference between those who practised and those who did not embrace the technologies was not statistically significant.

[1] https://www.humanitarianresponse.info/en/applications/kobotoolbox
[2] IBM® SPSS® Statistics is a powerful statistical software platform.

The income from crops differed between the CA method practiced and the crops grown. More revenue under mulching practice was generated from soybeans, beans, maize, and Irish potato, while the vegetables, groundnuts, and sweet potatoes were less under the same conditions. With zero tillage, groundnuts and Irish potato generated higher income. On the contrary, other crops brought more income for those who did not practice zero tillage. Furthermore, the income from livestock, primary cattle and pigs was huge though statistically significant compared to other animals reared by the smallholder farmers in the Dowa district, Malawi.

Key terms: Conservation Agriculture technology, crop yields, soil water conservation, crop varieties, mulching, farming, conventional tillage, income, livestock, conservation farming.

Acronyms and Abbreviations

AGRITEX: Agriculture Extension Offices

ANOVA: Analysis of Variance

CA: Conservation Agriculture

CBOs: Community-based organisation

CIMMYT: International Maize and Wheat Improving Center

CF: Conservation Farming

CT: Conservation Tillage

CSA: Climate Smart Agriculture

DARS: Department of Agricultural Research Services

DF: Development Fund

EU: European Union

FANRPAN: The Food, Agriculture and Natural Resources Policy Analysis Network

FAO: Food and Agriculture Organization

FEBRAPDP: The Brazilian Federation of No-till Farmers

GARTNER: Golden Valley Agricultural Research Trust

GDP: Gross Domestic Product

IIR and ACT: International Institute Of Rural Re-construction and Africa Conservation Tillage

IPPA: International Conference on Public Policy

IPEAME: Instituto de Pesquisas Agropecuarias Meridional

MACO: Ministry of Agriculture and Cooperatives

NGO: Non-Governmental Organizations

NEPAD: New Partnership for Africa´s Development

NORAD: Norwegian Agency for Development Cooperation

NLDP: National Livestock Development Project

NRC: Norwegian Church Aid

OPV: Open Pollinated Varieties

SAGCOT: Southern Agriculture Growth Corridor

SFM: Soil Fertility Management

SSS: Sub-Saharan Africa

SWC: Soil Water Conservation

TIP: Target Input Programme

TLC: Total Land Care

UK: United Kingdom

UN: United Nations

UNDP: United Nations Development Programme

USAID: United States Agency for International Development

ZCATF: Zimbabwe Conservation Agriculture Taskforce

ZNFU: Zambian National Farmers' Union

Chapter 1

1. Chapter Introduction

This chapter introduces the research topic and context, including the introduction, the origins of Conservation Agriculture (CA), the background to the study, the definition of CA, its history, and its importance. Also, the problem statement, followed by the study objectives and research hypothesis, are covered in this chapter. Lastly, the justification of the study, conceptual framework, and the organization of the study also make part of this chapter.

1.1 Introduction

The economy of Malawi is rooted in agriculture, with more than 85% of the population, rural-based, employed in the farming sector (GoM., 2006). Agriculture provides over two-thirds of the country's foreign exchange earnings while contributing close to 40% of the national gross domestic product (GDP) (Chirwa et al., 2008). Malawi's agricultural sector's composition entails the smallholder farmers and the estate subsectors, with more than 70 percent of agricultural Gross Domestic Product (GDP) coming from smallholder farmers (Banda., 2003; Derpsch., 2005). In Malawi, more than 80% of its population resides in rural areas (Fisher et al., 2018), with more than half of the rural households suffering from inadequate food each year. Around 40-50 percent of rural Malawi live in abject poverty (Gilbert et al., 2013) and are vulnerable to seasonal food shortages (Bunderson et al., 2017; Maher et al., 2015). Hence, agricultural innovation in CA technologies practice is essential for improving and increasing crop yield (World-watch Institute., 2011). However, the constraints to agricultural sustainability are getting direr as smallholder rural farmers are plunged into abject poverty, experiencing poor yields due to poor rainfall regimes and other environmental factors, including land degradation and droughts.

The extreme temperatures, high rainfall amounts/floods, and global warming have all impacted the viability of agriculture in Malawi. Given this status quo, remedies to reverse and adapt to these effects on soil are fundamental in improving agriculture to ensure sustainability and food security among smallholder farmers.

The Republic of Malawi, known as Nyasaland before her independence from British colonialism in 1963, is situated in the African continent's south-eastern part. The country sits across latitudes 9° and 17° south of the equator (Kaczan et al., 2013). The country's topography is highly variable, with a climate dwarfed by the Great Rift Valley, including Lake Malawi. Malawi is bordered in the North and Northeast by Tanzania, to the East, South, and Southeast by Mozambique, and to the West by Zambia. The current population of Malawi is around 18.62 million inhabitants, concentrated in an area of 118,480 km^2 and a population density of 130.4 people/km^2 (Gilbert et al., 2013).

Importing food in Malawi is not only complicated due to its poor and inconvenient transport infrastructure but costly as well, as it is a land-locked country (Knorr et al., 2007) with a dense population that lacks proper infrastructure for effective import business. As a result, food nutrition and security are relative to the crops and choices of the people in a given area. Approximately 2.8 million households in Malawi depend on farming (Chinsinga & O'Brien., 2008). The country's subtropical climate ensures one rainy season and one main harvest yearly. The change in rainfall patterns has negatively impacted the country's agricultural potential and food security (Knorr et al., 2007). Malawi's climate is sub-tropical and relatively dry, and monsoonal. Annual erratic rainfall of 800 mm and 2300 mm in the lowlands and northern highlands, respectively, have become the norm (Kaczan et al., 2013). The rains typically fall in the wet season -October to April - contingent on the Intertropical Convergence Zone (Kumbuyo et al., 2014). The 2014-16 El Nino and the 2016-17 La Nina effects affected the Southern African region, including Malawi (UN News Centre., 2016).

Putting into perspective, there has been a holy grail on the exacerbated frailty and vulnerability of agriculture and food security due to the climate change vagaries vectoring through drought, extreme temperatures, cyclones, and floods, for the last two decades. CA technologies have been 'prescribed' as a panacea to Malawi's ongoing food and nutrition problem. The capacity of CA to repair those organically damaged soils and improve soil properties and other biotic factors contribute to high crop yields (Hobbs et al., 2008). Before CA promotion, conventional farming was the default farming system in Malawi before 1980, and it had devastating effects on the soil and environment in general. Different organizations and governments initiated numerous projects to attract the attention of rural farmers to climate-smart agriculture (CSA) in Malawi (Erenstein., 2003; Andersson & D'Souza., 2014; Bunderson & Jere., 2008; Hobbs et al., 2008; Bunderson et al., 2017; Fisher et al., 2018). In a country where women constitute more than 50% of the population and provide a great deal of the labour force on farms, the adoption of CA technologies in farming and the participation of women in agriculture are of paramount importance. The United Nations[3] women press release states that "*rural women constitute one-fourth of the world's population. They account for a great proportion of the agricultural labour force, produce most of the food grown, especially in subsistence farming, and perform most unpaid care work in rural areas*". In addition, Malawi's smallholder farmers constitute 80% of the population (USAID., 2019). More so, 80 percent of the total agricultural production in Malawi comes from women, and women-headed households account for 25% of the total rural households (Face of Malawi., 2020).

1.2 Origins of Conservation Agriculture in Malawi

In Malawi, the efforts to improve farming practices can be traced back to the 1940s, when Conservation Farming (CF) was pursued but could not be integrated effectively into agricultural research and development programs due to a lack of a holistic and systematic approach (Banda., 1995). From the 1980s, the Bunda College of Agriculture and the Department of Agricultural Research Services (DARS) in Malawi revamped the efforts to increase yields and productivity by minimizing land damage and degradation by introducing CA/CF practices (Banda., 2002; Banda., 2003). DARS conducted both on-farm and on-station trials to study the impact of CA on improving soil properties and maize productivity and noted stable yields (Banda., 2003). Other stakeholders, including NGOs, promoted CA technologies to Malawi's smallholder farmers. The Malawian government collaborated with Sasakwa Global 2000 (SG 2000) in 1999/2000 to intensify the smallholder sector's food crop yields and agricultural productivity for food security (Knorr et al., 2007). The program was launched on top of the already underway 1998's Government of Malawi target input program (TIP), funded by the European Union and other donors to improve maize production among small-scale farmers (Ito et al., 2007). SG 2000, in conjunction with the government of Malawi, started CA promotion by introducing productivity-enhancing technologies to smallholders promoting maize, grain legumes, and roots and tubers (Knorr et al., 2007). The impact of CA on yields varied across agricultural seasons under Sasakwa's tutelage. Other organizations, including Total Land Care and International Maize and Wheat Improvement Center

[3] https://www.faceofmalawi.com/2020/03/31/the-face-of-malawianwomen-in-agriculture/

(CIMMYT), have also helped in this direction. Donor organizations such as the Development Fund (DF)- Norway, Norwegian Agency for Development Cooperation (NORAD), and the United Kingdom (UK) also put effort into helping small-scale farmers to improve agricultural systems and productivity. However, the most notable effort provided by these organizations was the introduction of CA systems for smallholder farmers.

CA technologies have proven practical and impactful in Latin America and the USA. There is an agreement on the effectiveness of CA technologies across academic texts (See details in chapter 2). However, in the context of sub-Saharan Africa (SSA), particularly Malawi, the impact of CA on the ground has mixed results. In Malawi, studies on CA focus more on managed plots (demonstration plots, on-farm CA, and project-funded CA) or formerly demonstration plots. What has been less explored are the impacts of CA technologies on specific crops in different local climates within Malawi's North and Central regions. The Government of Malawi launched the National Livestock Development Project (NLDP) in 1989 as part of the country's economic and social development framework. The project aimed to strengthen the smallholder private and commercialized produce and the non-viable public entities within the livestock sector. It also aimed at food security and income generation for poverty reduction.

Given this background, this study investigates the effects of CA technologies on specific crops grown primarily by smallholder farmers in the Dowa district in Malawi. The study also intends to broaden the smallholder's practice of CA, ensuring the understanding of improving agricultural yields, farmers' income from livestock and crops, and food security in Malawi.

1.3 Background of the Study

Overview

This chapter covers the definition of Conservation Agriculture, its role in farming, and the agricultural principles which guide the technology's practice. The importance of studying CA in Malawi and the history of CA in Malawi have also been covered.

1.3.1 Definition of Conservation Agriculture

CA is a basket of technologies meant to reverse the catastrophic effects of land degradation that emanate from poor conventional farming methods (Derpsch., 2008; Derpsch & Friedrich., 2009; Corbeels et al., 2015). Traditional agricultural methods employed by smallholders, such as conventional farming- tillage, ploughing, heavy weeding, and ripping, are to be replaced by the better soil fertility and water conservation methods of CA (Bunderson et al., 2017; Giller et al., 2009; Ito et al., 2007). In simpler terms, CA is best understood by three major principles which are i) to have as far less or minimal soil tilling or digging (zero or minimum soil tillage), ii) to maintain as much soil/ground cover as possible using mulching/ dead crop residue iii) Practice crop rotation regimes/diversity, crop associations and intercropping. A simultaneous application of these three principles is termed "True CA adoption." (Derpsch., 2008).

Briefly, conventional farming practices have negatively impacted yields and crop production. Conservation farming/agriculture is the technology believed to be essential in reversing land degradation caused by traditional farming, remediating the damaged soil structure, and reinforcing soils for climate-induced stresses.

CA is adaptable to all climates, soils, and crops, including annual crops, horticultural crops, and tree crops, including fruit and forest (Derpsch., 2003; Derpsch., 2008). As a result of CA application in many large cropping systems worldwide, such as Brazil, Canada, the USA, and Argentina, several improvements have been made. For example, CA has been responsible for yield improvement and better farm and agricultural productivity, reduction in petroleum use and costs, and farm labour demands (Derpsch & Benites., 2003). It has also resulted in the reduced requirement of external inputs due to significant increases in organic matter, reduced erosion, and the return of biological diversity to the soil, particularly earthworms.

1.3.2 The Importance of Conservation Agriculture

According to the Zimbabwean Conservation Agriculture Taskforce (ZCATF), Conservation agriculture can significantly boost production and improve farming households' food security and livelihoods (Harford., 2009). Conservation agriculture provides the necessary agronomical management tools to conserve natural resources of soil and water and guarantee sustainable production and improved harvests. Crop yields are believed to improve, particularly in dry and semi-arid areas, through the CA principles mentioned above -no-tillage, permanent soil cover, crop rotation/intercropping, herbicides, and seed varieties. CA remediate degraded soils caused by conventional methods of farming. It reverses soil degradation, reduces erosion, and improves drainage, infiltration, and soil organic structure (Marongwe et al., 2011). Thus, no-till/ minimum tillage combined with intercropping or crop rotations with different rooting patterns, a more extensive network or root channels plus macropores in the soil established, thereby helping infiltration to deeper depths (Hobbs., 2007; Hobbs et al., 2008).

CA is essential for the resource-strained poor farmers in Malawi due to its less demand on labour, time-saving, and maximum yields. However, Mazvimavi and Twomlow (2009) forwarded that, issues such as shortage of draft power and labour, unavailability of suitable equipment, lack of proper policies and institutional support to the smallholder farmers, and lack of capital for inputs generally make the adoption of CA techniques to be unattractive to the rural farmers.

1.3.3 History of Conservation Agriculture

The foundations of CA are embedded more in farming societies than in the scientific community and are backed by development-oriented agriculturalists. CA's diffusion has been more farmer-driven (Kassam et al., 2015). From the 1930s and for the next 75 years, a move to moot the enactment of sustainable ways of farming came to the fore (Hobbs et al., 2008). The farming community members in the USA pushed for a reduced tillage system that uses minimal/no fossil fuels, minimises surface run-off plus soil erosion, and combats the destruction of soil organic matter (Hobbs et al., 2008). The zero-tillage practice came into existence intending to purge soil degradation in the dust bowl states of the USA and has been extensively adopted by farmers of different scales in both North and South America (Kassam., 2015). The first 50 years were the start of the conservation tillage (CT) movement, and today, a large percentage of agricultural land is cropped using these principles (Hobbs et al., 2008). CA and No-tillage in the above geographies have been above 50% and approaching 100% (in South America), respectively (Kassam et al., 2015). Brazil's ''Zero-tillage revolution'' approach to farming has been viewed as a desirable hypothetical panacea to combating and reversing soil degradation and increasing land productivity in SSA (Hobbs., 2007; Fowler & Rockstrom., 2001).

On the other hand, Baker et al. (2006) noted in their book 'No-tillage seeding' that, "As soon as the modern concept of reduced tillage was recognized, everyone, it seems, invented a new name to describe the process." A list of 14 different names refers to reduced tillage practice cropped out, juxtaposed to the rationale behind naming the technologies. Baker et al. (2002) further reviews the equipment and mechanization demands of no-tillage. The demands were defined as follows;

"the collective umbrella term is commonly given to no-tillage, direct-drilling, minimum-tillage, or ridge-tillage to denote that the specific practice has a conservation goal of some nature. Usually, keeping at least 30% surface cover by residues characterizes the lower classification limit for conservation-tillage. Still, other conservation objectives for the practice include conserving time, fuel, earthworms, soil water, soil structure, and nutrients. Thus, residue levels alone do not adequately describe conservation tillage practices (Baker et al., 2002)."

However, misunderstanding and confusion filled the whole farming community, not only them but also the agricultural scientists, on what constitutes CA technology. Therefore, Food and Agriculture Organization (FAO.) proffered the term 'conservation agriculture[4] and it outlined CA goals as follows:

Conservation agriculture (CA) aims to conserve, improve, and make more efficient use of natural resources through integrated management of available soil, water, and biological resources combined with external inputs. As a result, it contributed to environmental conservation and enhanced and sustained agricultural production. Therefore, it can also be considered resource-efficient or resource-effective agriculture. (FAO.)

1.4 Problem Statement

Food security has become an increasing challenge in Malawi, a nation whose backbone is hinged on agriculture and smallholder subsistence farming. Malawi is a developing country with more than two-fifths of its population residing in rural areas, unable to meet their basic daily food requirements (Mukherjee & Benson., 2003). Some of Malawi's significant menaces

[4] http://www.fao.org/ag/ca

to food security emanate from climate change whims, poor agricultural practices disturbing soil structure and fertility, poverty, and a fast-growing population. Thus, per capita, food production in Malawi has constantly decreased (Chirwa et al., 2008).

Conventional tillage (CT) has been the holy grail in many rural societies of Malawi and is reproached for instigating land degradation. CT involves tilling/digging the land, destroying soil structure, and depleting soil organic matter content (Baker et al., 2002; Baker et al., 2007). It also involves the removal of ground/soil cover in the form of dead crops or crop residues, which in turn accelerates surface water run-off. As a result, it hastens soil organic carbon decline, compromising soil fertility and water retention capacity (Galani et al., 2021). Furthermore, mono-cropping has been rampant under this conventional farming practice, providing leeway for marauding pests and crop diseases, negatively affecting yields.

Climate change effects have also fortified the grave impacts on agricultural production in Malawi. In North and Central Malawi, agricultural production has been expunged by the recurrent water scarcity induced by unreliable rainfall regimes, extreme temperatures, and intermittent rainfall coupled with high evapotranspiration. Adapting to climate impacts and reversing land degradation would ensure high agricultural productivity and a food-secure nation.

Therefore, coping strategies which could ameliorate the egregious effects of climate change and land degradation, and reverse soil fertility decline, are essential in making agriculture production sustainable and improving crop yields for food security in Malawi. For decades, efforts to disseminate Climate Smart Agriculture (Kimaro et al., 2016) and Conservation Agriculture (CA) technologies among rural farmers have been ongoing in SSA and Malawi. However, little is known about the impact of CA technologies on crop production within North and central Malawi's agroecological conditions. Thus, the study aims to assess the effects of CA technologies on the yields of maize, Irish potato, soybeans, beans, vegetables, groundnuts, and sweet potatoes in the Dowa district in Malawi. Knowing the revenue these crops generate for the smallholder farmer to improve their livelihood is also essential. Furthermore, the above-mentioned crops constitute 100% of the farm crops grown by smallholders in Malawi. The failure to attain an excellent sustainable harvest from the grown crops would negatively impact the food security of rural households in Malawi. Thus, it is fundamental to understand the compatibility and effectiveness of the CA technologies on/with these crops.

1.5 Research Objectives

This study's primary objective is to determine ***if various Conservation Agriculture practices boost crop yields of various farm commodities***[5] ***and improve crop harvests, and income generated by smallholder farmers in the Dowa*** **district in Malawi.** *Below are the proffered* specific objectives to address the objective.

1.5.0 Specific Objectives:

1. To determine the impact of CA practices on eight specific crop yields (maize, Irish potato, soybeans, beans, vegetables, groundnuts, and sweet potatoes) grown by smallholder farmers in the Dowa district of Malawi
2. To assess the impact of conservation agriculture practices on income generation by smallholder farmers in the Dowa district.
3. To examine the role of livestock on income generation thus lowering farm risk of smallholder farmers in the Dowa district in Malawi.

1.5.1 Research Hypothesis

Null Hypothesis: *Conservation Agriculture technologies do not improve crop yields and income for smallholder farms.*

Alternate Hypothesis: *Conservation Agriculture technologies improve crop yields and income for smallholder farms.*

1.6 Justification of the study

Many organizations have promoted CA in Malawi, particularly in the south and central parts of the country. However, food insecurity, malnutrition, hunger, and starvation pose a simultaneous drudgery impact. A lot of literature on CA in Africa and Malawi has documented CA adoption patterns and for various reasons, CA adoption is low and slow among smallholders (Ngwira et al., 2014) (see Chapter 2: Challenges to Adoption). However, answers to the following questions are lacking for Malawi conditions: Do CA technologies

[5] maize, Irish potato, soyabeans, beans, vegetables, groundnuts, and sweet potatoes

zero-tillage, cropping systems, and mulching, - impact agricultural yields of specific crops in smallholder farms in the Dowa district in Malawi? In addition, does CA practice on specific crops such as maize, Irish potato, soybeans, beans, vegetables, groundnuts, and sweet potatoes in smallholder farms enhances their revenues and hence livelihoods? Finally, what is the role of livestock in enhancing the smallholder farmers' income and revenue to impact their livelihoods? Understanding these nuances would aid in promoting the technologies in different areas.

Furthermore, to ensure an improvement of agricultural productivity in rural Malawi, it is paramount to have an in-depth understanding of the compatibility of each CA technology on specific crops in this study, such as maize, Irish potato, soybeans, beans, vegetables, groundnuts, and sweet potatoes. These crops make up the dietary calories and nutrition of Malawi's population. Moreover, as the crops are mainly grown for subsistence, it is fundamental to provide panaceas to improve harvests and crop production, with less labour and less input demand. Hence, this study is imperative in determining the effects of CA technologies on crop yields grown by smallholder farmers in North and Central Malawi.

Moreover, little has been done in Malawi to understand the effect of CA on specific crops, which makes the staple of Malawi in districts such as Dowa, in Malawi. Therefore, this study aims to bring to the fore the impact of CA technologies on specific crops' yields, such as maize, Irish potato, soybeans, beans, vegetables, groundnuts, and sweet potatoes. The research is also fundamental in elucidating how smallholders in Malawi's two regions are devoted to improving yield productivity and promoting food security. The study, as a result, will potentially help development agencies, donors, project implementors, policymakers, and the government with better information to bolster their agricultural intervention initiatives. (Very ambitious goals and can be moderated somewhat because this small study will not solve all the problems associated with food production and insecurity).

Many studies regarding the adoption of CA systems have been done in Malawi over the past two decades (Banda., 2002; Giller et al., 2009; Thierfelder et al., 2013; Ngwira., 2014; Jumbe., 2016; Bunderson et al., 2017; Giller et al., 2021). However, due to limited empirical data, it was challenging to precisely answer these questions; does CA technologies' uptake in the Dowa district, impact and improve crop yields of smallholder farmers? Additionally, comprehending the importance and effects of CA technologies on yields would allow one to know the impact it has on smallholders' income and food security in Malawi. Therefore, the government and other stakeholders would refocus their assistance and support on these smallholders, from other agricultural methods to CA in North and Central Malawi.

1.7 Conceptual Framework

1.7.1 Understanding Conservation Agriculture

'Conservation agriculture' simply refers to a farming approach that does not harm the land and environment (FAO., 2008). Different scholars have put forward many definitions; however, FAO[6] has provided one which could be termed a standard one which stipulates that:

"CA is a resource-saving agricultural crop production concept that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing the natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes."

Thus, CA is a grouping or a simultaneous amalgamation of specific technologies which are aimed at conserving land and environment, which entails:

- Zero soil disturbance or reduced tillage
- Permanent soil cover using dead crops or cover crops—minimum 25-30% ground cover, if possible, entirely, and continuously throughout the year
- Intercropping and diversification of crop rotations
- Herbicides used to control weeds

Fig 1 below shows the CA cycle from minimum soil disturbance, permanent soil cover, and diversified crop rotations. Complete or 'true' conservation agriculture is realized after successfully applying these principles simultaneously in each smallholder farmer's field

[6] http://www.fao.org/ag/ca

(Erenstein., 2003). CA technologies have been vitally important because of their direct effect on soil chemistry and organic structure.

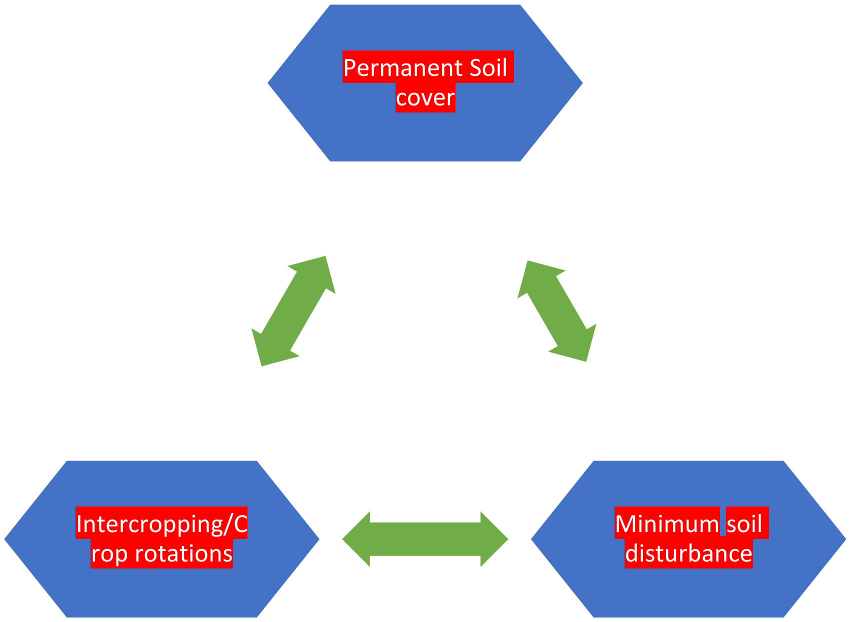

Figure 1. Key conservation agriculture principles.

The benefits of conservation agriculture include saving the hiring of draft animals or machinery, increased and stable yields, the buffering of crops against acute drought and other climate problems, timesaving, labour-saving, crop diversification and associations, improvement in water quality- retention and drainage, increased soil fertility, improved biotic activity in the soil, and improved food security and nutrition.

1.7.2 Defining a Smallholder farmer

There are many definitions for smallholder farmers. In Zimbabwe, the term "smallholder farmers" denotes farmers working on fields in rural, communal, and resettlement/plot areas, stretching further to include co-operative farmers (Makuvaro et al., 2014). Waddington et al. (2004) stated that smallholder farmers are associated with a limited resource base and operate on a "low input – low output" basis. Thus, the poor rural people whose lives are hinged on agriculture partly or exclusively to survive and acquire food are known as smallholder farmers (Umar., 2014). Another description of smallholder farmers has been "risk minimizers rather than yield maximizers" (Rockstrom., 1999). Umar (2014) used the definition of peasants to understand smallholder farmers as households that "derive their livelihoods mainly but not exclusively from agriculture." These households, Umar (2014) noted, "predominantly utilize labor in farm production, engage in low input and output markets, and are both consumers and producers of their agricultural products and services." Therefore, in this study, Umar's definition of a smallholder as a peasant whose livelihood dwells much but not exclusively on agriculture will be used to understand the farmers' CA adoption patterns.

1.7.3 The concept of Adoption

Kapalasa (2013) defined the term adoption as "the degree of the use of a new technology in long-run equilibrium when the farmer has full information about the new technology and its potential." Grabowski (2011) conceptualised adoption as how an individual effectually applies new technology after getting information on its purpose and related advantages. Neither do adoption studies consistently define the CA package being practiced nor do they account for the ambiguities of partial adoption (Andersson & D'Souza., 2014; Giller et al., 2015). CA adopters generally remodel the CA package to suit their ecology and socio-economic circumstances (Mazvimavi & Twomlow., 2009; Andersson & D'Souza., 2014).

A large number of smallholder farmers reported to be practising CA in Southern Africa are applying minimum tillage bundled with improved soil fertility techniques (Baudron et al., 2007; Mazvimavi & Twomlow., 2009), while diversified crop rotation may be partial. The use of crop residues may be limited. In effect, farmers' assessment and evaluation of the CA technologies enables them to cherry-pick and adopt those components of the package believed most useful (Mazvimavi & Twomlow., 2009), and even so, this may only be applied to a limited portion of their land. Furthermore, adoption rates vary due to numerous factors ranging from crop type (subsistence and commercial), gender, and length of experience with CA (Mazvimavi., 2016). Many scholars have accurately argued that for CA's benefits to be realised, all three principles must be simultaneously implemented in the field (Erenstein., 2003), while other scholars have forwarded that both a simultaneous application of CA principles or the practice of single CA technology would provide the much needed CA benefits (Mazvimavi., 2016).

1.8 Organization of the Study

For coherence and systematic flow of ideas, this thesis is presented in seven chapters, and reference as below:

Chapter 1 *provides an introduction, background to the study, the definition and history of CA, and the rationale for studying CA's impact on crop yields. Next, the chapter outlines the conceptual* *framework, research hypothesis, the research problem, research objectives that would aid in understanding key issues, and the likely panacea to the constraints.*

Chapter 2 *reviews the existing literature on the history of conservation agriculture, the CA adoption and practice globally, in Africa, and its evolution in Southern Africa and Malawi. Also, the chapter covers the inception of CA in Malawi, current practices, challenges, and gaps in CA from the literature.*

Chapter 3 *summarises the study methodology, including the data collection methods, sampling techniques, work ethics, ANOVA test, and SPSS software for data analysis.*

Chapter 4 *presents the results and directly addresses the three specific objectives of the study. It covers the descriptive statistics and analysis sections.*

Chapter 5 *discusses the study results and answers the study's research objectives, including the effect of CA technologies on crop yields, the impact on income generated from crops, and the importance of livestock on smallholder farmers' income.*

Chapter 6 *finishes with a concluding summary and recommendations that would aid different stakeholders assisting smallholder farmers, policymakers, and the government.*

Chapter 2

2. Review of Related Literature

Overview

This chapter covers the literature on the spread of CA, the practice, and the origins of CA technology, at a global level, in Africa, and Southern Africa, with a particular focus on Zimbabwe, Zambia, and Tanzania. The criteria for choosing the three countries were first based on their proximity to Malawi. In addition, maize is a staple in Malawi, Zimbabwe, Zambia, and Tanzania. Also, beans, soybean, and groundnuts make up these countries' important dietary food nutrition. Zimbabwe is one of the first countries to practice CA in Southern Africa, and it acted as a model for Malawi's CA promotion. Zambia has seen a lot of CA investments and promotions, and it has registered CA successes in the region (Baudron et al., 2007).

Several studies and research have established the adoption of CA systems by smallholder farmers (Erenstein., 2003; Baudron et al., 2007; Giller et al., 2009; Andersson & D'Souza., 2014; Farooq & Siddique., 2014; Umar & Kapembwa., 2020) in various sub-Saharan African countries. However, the recorded results were asymmetrical, contingent on numerous factors ranging from rainfall regions, soils, climate factors, capabilities, and 'functioning's'/capabilities of the smallholder farmers. Poor farming methods by the locals have also succumbed to such a decrease and poor yields across seasons. Subsequently, the galloping poverty and increasing food insecurity among rural folks in Malawi prompted or compelled various organizations to bring different agricultural interventions to the fore. Donors, NGOs, international development organizations, and the government of Malawi became the promoters of new agricultural approaches and interventions for smallholder farmers.

2.1 Conservation Agriculture Globally

Conventional agriculture was the case worldwide until the 1930s when the dust bowl of the USA shifted to conservation tillage to reverse soil degradation and the likeliness of desertification (Derpsch & Friedrich., 2009). Different geographies embraced CA practices, including North America, South, Latin America, Australia, and Asia. CA is estimated to be practiced on approximately 100 million hectares across the globe, demonstrating its adaptability to all kinds of climates, cropping conditions, and soil types (Derpsch & Friedrich., 2009). It is essential to highlight the impact of these measures, which halts soil erosion, improves organic matter content, and soil fertility, soil water conservation has been well managed, and yields have increased with time (ibid). Fig 3 below shows the distribution of CA across the globe and the level of CA practiced.

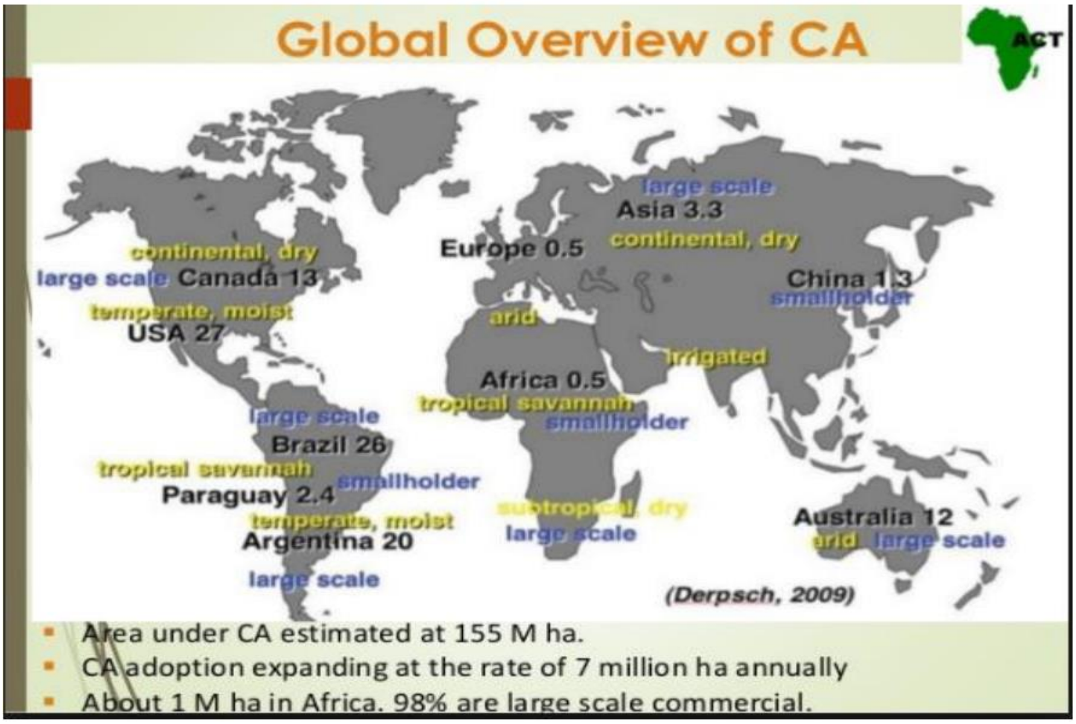

Figure 2. The adoption of Conservation Agriculture across the world. Source: (Derpsch., 2009)

The adoption of CA in *Latin and South America* was first launched in 1971 with no-tillage trials by the Instituto de Pesquisas Agropecuarias Meridional, IPEAME, in Londrina, Paraná State, Brazil, in cooperation with a GTZ (German aid agency) project (Derpsch., 2008). The FEBRAPDP (The Brazilian Federation of No-till Farmers) reported that in 2005/06 season, 25.5 million hectares of No-tillage practice took place in this country (Derpsch & Friedrich., 2009). The positive impact of CA practices has been realised in these countries. For example, in Brazil, yields of soybeans have increased by 63% (Derpsch et al., 1991). Thus, CA's stability and ability to increase profits, and reduce weeding demands, have led to high adoption.

More than 14 million hectares of land have been put under CA in North America, particularly Canada. On average, the CA technology is used on 46% of the cropped area in North America. (Derpsch & Friedrich., 2009). Likewise, in Australia and New Zealand, No-tillage has been reported to have reached 12 million ha in each country (Derpsch and Friedrich 2009). More importantly, the reaped benefits from CA in Australia, which entail water, time, fuel savings, and yield increase, have led to the (Derpsch & Friedrich., 2009).

CA adoption in *Asia*, more specifically China and Kazakhstan, boomed, with more than a million hectares reported to be under CA/no-tillage practice, in each country. In the last years, a significant expansion of the area under No-tillage has been reported in Asia, especially in China and Kazakhstan, where more than a million ha have been reported in each country. China and other countries in Asia have also adopted Conservation Agriculture practices. However, in China, the technology is generally referred to as conservation tillage and involves mulch tillage and No-tillage (Derpsch & Friedrich., 2009). No-tillage makes up about 50% of conservation tillage in China, and they allow for low-disturbance subsoiling or ripping in their No-tillage fields (Derpsch & Friedrich., 2009).

2.2 Conservation Agriculture in Africa

Generally, the scale of CA in Africa has been reported to be embraced with limited intensities (Kodzwa et al., 2020). However, over 50 years after the introduction of CA (through adoption and research extension), it is still limited and 'piecemeal' with less than one percent of arable land under CA (Brown et al., 2017). Around 457 230ha under CA in SSA were reported in the 2008/09 season (Kassam et al., 2015), further galloping up to 981 000 *ha* in 2011. About 1 223 340 *ha* of farmland were put under CA in SSA by the year 2013, meaning an increase of 157% in 5 years (Kassam et al., 2015). In East Africa, particularly in Kenya and Tanzania, the area under CA in *ha* is reported to be still small as the primary focus of promotion is on small-scale farmers (Derpsch & Friedrich., 2009). However, a steady increase of around 100 000 small-scale farmers in the two countries (ibid). In addition, the CA adoption area in Kenya and Tanzania has reached 20 000 *ha*. In west Africa, according to Jim Findlay's personal communication records, Ghana boasts a sum area under zero tillage estimated to be around 25 000 to 30 000 *ha* (ibid). About 100,000 smallholder farmers across Ghana were reported to be practising no-tillage on 0.3 *ha* to 0.75 *ha* on their farmlands following the subsequent slashing and applying systemic herbicide and crop desiccant (Derpsch & Friedrich., 2009).

CA was incorporated into the policies of different governments, like as Zimbabwe, Malawi, Tanzania, Zambia, and Mozambique (Giller et al., 2015) to support smallholder farming, together with the assistance of international development organisations. Subsequently, in Zimbabwe from the 1980s, CA technologies have been appraised and vigorously promoted, including zero-tillage tied ridging; mulch and clean ripping; no-tillage strip cropping; hand-hoeing or zero till; tied furrows (specifically for semi-arid climates/areas) and open plough furrow planting followed by mid-season tied ridging (Twomlow et al., 2008). Nevertheless, despite nearly two decades of development and promotion by the national extension program and numerous other projects, adoption has been shallow in the smallholder sector (Gowing & Palmer., 2008) compared to other continents such as South America, North America, and Europe due to various constraints (Hobbs., 2007; Derpsch., 2008).

2.3 Evolution of Conservation Agriculture in Southern Africa

Different NGOs and government schemes have promoted the adoption of CA in sub-Saharan Africa through independent and joint projects and programmes. The spread of CA in Africa was heterogeneous. Continental organisations such New Partnership for Africa´s Development (NEPAD) and the Alliance for a Green Revolution (AGRA) in Africa have stepped up efforts to promote CA adoption in SSA, banking on its great prospective to contribute to economic growth, poverty alleviation, reversal of degraded land, food security and climate change adaptation and mitigation (Anderson & Giller., 2012). However, the uptake of the technology in SSA has been low and slow (Fisher., 2018), with around 1% of the total arable land area under CA (Hove et al., 2011). Innovative participatory approaches to ensure supply-chains availability for producing CA equipment specifically for poor-resourced smallholder farmers have taken centre stage in CA promotion (Kassam et al., 2015).

In Southern Africa, the definition of CA across national borders could ostensibly differ following the reframing of the technology from resource-saving to production and productivity-increasing concept (Andersson., 2014). For example, the Zambian Conservation Farming Unit employs the term Conservation Farming (CF) to refer to various practices that apply to the three CA principles. Furthermore, it has begun associating Conservation Agriculture with less reliance on external inputs and agroforestry (Andersson., 2014). In contrast, the Zimbabwean Conservation Agriculture Taskforce (ZCATF)' use of the term embodies a distinct manual practice (manual hand hoeing/digging of permanent basins in which crops are grown/planted) together with the second principle of CA-permanent soil cover. Large-scale Conservation Agriculture promotion began in Zambia, promoted as conservation farming, where a combination of hand-hoe and planting basin-based system dubbed Conservation Farming hinged principally on the farming techniques initiated by a Zimbabwean farmer, Brian Oldrieve, in the 80s decade.

Furthermore, farmer field schools have been used to encourage and improve farmers' comprehension of the underlying CA principles and the best feasible ways to localise the technologies (Banda., 2002; Bunderson., 2008; Mutsvangwa., 2020). Zero-tillage, mulching, crop rotations, intercropping, and improved seeds are the technologies that make CA. Specifically, in sub-Saharan Africa's context, where there are many resource-poor farmers, farmer field schools are fundamental in teaching CA knowledge and systems which are indispensable in addressing climate change vagaries, droughts, high energy costs, and soil degradation, environmental catastrophes, and high labour demand on the farm. Increased and sustainable crop yields or agricultural harvests are contingent on a concoction of factors related to CA adoption in the wake of natural climatic paradoxes. Cropping systems (intercropping, mixed cropping, monocropping, crop rotation), soil water conservation practices, soil fertility conservation practices, labour availability, income to acquire resources/inputs, improved seed varieties, and zero/minimum tillage, are all fundamental in realising high yields (Derpsch., 2003; Derpsch., 2008; Giller., 2009, Corbeels., 2015). Thus, this study is to understand the impact of CA technologies on crop yields. Giller (2009) indicated that in the first year and over time, crop yield (output) frequently improves substantially under conservation agriculture, and this is a significant factor in farm-level profitability and the most documented in the literature (Giller., 2009). The impacts of mulching, crop rotation, intercropping, soil fertility management, and seed varieties on crop yields vary with seasons.

a) No-tillage

Reduction in land tilling saves the need to achieve zero tillage, however, the process may comprise managed systems of tillage seeding that would not harm or disturb at most 30% of the soil surface. Hence, the objectives are to lower soil disturbance, reduce production costs, double profitability, and use less energy.

b) Permanent soil cover

The review by (Kumar & Goh., 2000) documents the impact of crop residues on crop yields when used as mulch. Crop residue comes from dead crops – previous crops left anchored post-harvest or when legumes (cover crops) are grown and killed to provide mulch which acts as the ground cover. However, some external sources of mulch -manure and others- could also be used. Kumar and Goh (2000) also noted the effects of soil quality management practices, reverse soil degradation, and crop yield improvement. Conclusively, (Kumar & Goh., 2000) reported that crop residues of cultivated crops have more significant yield benefits through their effects on soil biological and physical functions.

c) Rotations

Rotation of crops is one of the oldest indigenous and cultural methods of plant and disease control. The rotation of different crops helps in water infiltration (Hobbs et al., 2008). An increment of microbial diversity checkmates pathogenic organisms, thus reducing pests and disease and increasing agricultural productivity (ibid).

2.4 Case study 1: Conservation Agriculture as practiced in Zimbabwe

Conservation agriculture has been promoted in different parts of Zimbabwe for the past 20 or more years (Mutsvangwa., 2020). Zimbabwe is one of the few countries in Southern Africa to practice CA. CA is purported to ensure an improved soil structure, soil fertility, and yields stability in rural smallholder farms (Mazvimavi et al., 2010). CA was incorporated into the government policy in Zimbabwe (Giller et al., 2015) to support smallholder farming, together with the assistance of international development organisations. Sustainability and increased agricultural productivity will enhance the climate change resilience of crops and food security (Mugandani & Mafongoya., 2019).

Conservation Agriculture in Zimbabwe is understood in a narrower term as Conservation farming (CF) which heralds the specific practice of planting basins and (permanent) soil cover. Farmers with resources such as animals and implements could adopt CA technologies faster than those farmers short of draught power or equipment. The standard CA practice in Zimbabwe is marked by the following eight technologies proposed by Pedzisai (2016): winter weeding, planting basins, manure application, use of mulch, inorganic fertiliser, and top-dressing fertilizer application, early planting, crop rotation and intercropping, and timely weeding (Mazvimavi & Twomlow., 2009). However, Giller et al. (2015) noted that some farmers are practising a few components or techniques of CA (Giller et al., 2015). Of the proposed CA standard practice by Pedzisai (2016), planting basins, localised manure application, and timely weeding have been adopted by most smallholder farmers in Zimbabwe, while crop rotation is receiving minor attention (Mugandani & Mafongoya., 2019). Harford (2009) has added that less than 40% of farmers have access to draught power.

Maize is the major crop that dominates Zimbabwe's smallholder agricultural sector and other cereal crops. Other legume crops such as cowpea, soybeans, and various types are unsystematically grown and rotated by smallholder farmers in different farming districts. Several studies have been conducted in Zimbabwe on smallholder farmer agriculture (Baudron et al., 2015). It is estimated that around 8.3% of arable land in Zimbabwe is under conservation agriculture (Richards et al., 2014), with traditional farming methods and other land use activities occupying the rest of the land.

According to Mugandani and Mafongoya (2019) on the uptake of CA by smallholder farmers in Chivi, Murehwa, and Mutoko, the rural farmers are fully aware of the social, environmental, and economic factors benefits of CA. CA was introduced in Murehwa and Mutoko in 2004/5 by FAO and three Farmers Union of Zimbabwe. The Department for International Development (DFID) and other NGOs had their introduction of CA in Chivi. Although CA is touted for the 'poor' rural farmers whose livelihoods are hinged on agriculture, CA also seeks to solve the lack of access to draft power, which is a hurdle to cropping by smallholder farmers in Zimbabwe (Matiza et al., 2005). The pace and level of CA uptake across the landscape of Zimbabwe are not homogeneous partly because less than 12% of smallholder farmer households in South-western Zimbabwe rely or depend entirely on agriculture, as there are other diverse off-farm livelihood strategies they embark upon (Mutsvangwa., 2020).

2.4.1 Current CA Practice in Zimbabwe.

The promotion of Conservation Agriculture to the farmers in Zimbabwe has been received as a win-win type of technology desperately needed on their farms to improve crop yields (in the long term) while simultaneously conserving the environment (Giller., 2009; Marongwe et al., 2011; Marongwe et al., 2012). Both on-station and on-farm trials have demonstrated the potential of crop yield increase through Conservation agriculture by margins ranging from 5% to 90% (Mazvimavi & Twomlow., 2009). As a result, the adoption of CA technologies is embraced in different phases of agriculture, including tillage and planting seasons, weeding, soil fertility management, soil water management, cover crops, and mulching.

Tillage and Planting

CA was introduced to prevent soil disturbance through tillage by introducing dibble sticks which would open a small space in the soil for seed planting. In Zimbabwe, no-tillage adoption has been realised through hand-dug planting basins that were marketed mainly to those without access to draft animal power (Twomlow et al., 2008). However, the sizes of planting basins used in Zimbabwe differ with the area and organization providing technical support (Mupangwa et al., 2017). The basins usually range from 15cm long, 15cm wide, and ten up to 20cm deep (Twomlow et al., 2008), and they are used each season with another variation in depths, such as 10cm/less to minimise breaking down of soil structure (Mupangwa et al., 2017) and to make sure to break the plough develops because of long periods of conventional tillage (Nyamangara et al., 2013).

A study by Rusinamhodzi et al. (2013), in Murehwa, Zimbabwe, indicated more and more maize grain yield in conventional tillage farms than in conservation agriculture farms under planting basins. Planting basins did not help with moisture conservation during periods of poor rainfall distribution. Moreover, Rusinamhodzi et al. (2013) reported that 98% of the farmers in Murehwa are using planting basins but only on a small piece of land (0.2 ha per farm) as the no-tillage method is increasing labour burden compared to crop yield. However, the use of inorganic fertilizer has proven to positively impact outcomes consistently, although, access and affordability of the resource are dire for many farmers (Rusinamhodzi et al., 2013). It has been reported that farmers have realised improved and profitable yields on CA farms, with a mean yield of 1.5 tons/ha compared to 1 tonne/ha under CT practices (ibid).

A study conducted by Makuvaro et al. (2014) in semi-arid central and western regions of Zimbabwe, which are lower Gweru and Lupane, reported that both CT and CA) systems are practiced. The predominant system in these two communal areas is CT which involves ox or donkey-drawn plough or a combination of both; however, more than half of the farmers in

Lupane also use planting basins (Makuvaro et al., 2014). Farmers in these two areas practice conventional and conservation farming on different farms. Around 29% of farmers in Lupane also practice zero tillage in some of their fields, while 10% of those in Lower Gweru practice the 'Chibhakera'-system of hand digging the whole area to plant (Makuvaro et al., 2014). Hence farmers use both farming systems when preparing the land and planting. Twomlow et al. (2008) established from their 13-district pilot study in Zimbabwe that crop yields increase, on average, by 15 to 300% in a period of three seasons (2004/05 to 2006/07) when using planting basins, however, it is contingent on rainfall regimes, soil type and fertility (Twomlow et al., 2008).

In a study conducted in Zimbabwe's agro regions by Mupangwa et al. (2017) to determine the effect of four tillage systems (conventional ploughing, planting basins, rip-line, and animal traction direct seeding systems) on maize, cowpea, and soybean yields. They have reported no difference in maize crop yield in high and low-rainfall areas. However, CA has recorded more maize yield under medium rainfall than conventional practice. The same authors reported that yields depended on sites and rainfall patterns across regions and that cowpea yields did not respond to CA tillage practices (Mupangwa et al., 2017).

In their study, "lessons from the field…" in Zimbabwe, Twomlow et al. (2008) documented that Precision Conservation Agriculture (PCA) that is practiced in Zimbabwe has consistently increased cereal yields by an average of 50 to 200% in more than 40 000 smallholder farmers. However, the yield increase varied by rainfall amounts, soil type, and soil fertility. Precision Conservation Agriculture enables smallholder farmers to manage their inputs well and combine improved fertility and seed for higher productivity. In three agricultural seasons, Twomlow et al. (2008) reported that yields have consistently increased by 15 to 300% in plots under planting basins and Conventional farming. With tillage and planting basins, the amount of water and soil fertility augmentation within the basins helps lessen the risk of crop failure (Twomlow et al., 2008). However, it has to be highlighted that the farmers in the Southern part of Zimbabwe are adopting the technology slowly, noted Twomlow et al. (2008)

Cover crops and Mulch

The types of crops grown by smallholder farmers also play a part in attaining the second principle of CA, which is permanent soil cover through crop residue and planting legume crops to provide surface cover. Smallholder farmers in Zimbabwe grow a variety of crops, including maize (Zea mays L.), sorghum, groundnuts, cowpeas, sugar beans, and pumpkins which are appropriate for soil cover/ cover plant purposes (Marongwe et al., 2012; Mazvimavi., 2016; Mazvimavi et al., 2010). The importance and choice of the crops grown are influenced by their contribution to food security, improved livelihoods, and income generation capacity (Makuvaro et al., 2014). Maize is the most popular and grown crop in Zimbabwe.

Crop rotation and Intercropping

Rotations and Intercropping methods have been promoted in Zimbabwe since the early 1970s, so it is not entirely a new model for farmers. ZCATF propagates that "Mixing different crops in one field echoes processes found in nature and can maximize plant nutrient use through synergy between different crops. Conservation agriculture encourages profitable and agronomically efficient rotations: usually cereal and legumes or cash crops (Harford., 2009)." Together, CA practices provide the following advantages: replenishing soil fertility as intercropping with nitrogen-fixing legumes adds up 'top dressing fertilizer' to the soil fertility richness. In addition, new crops are introduced through crop rotations, disease, and pests, and weeds are controlled by breaking the life cycle on one field. Thus, the risk of sheer crop failure is minimised by having multi-crops in one field during droughts and/or disease outbreaks.

A study done by Rusinamhodzi et al. (2011) in Zimbabwe has shown a significant improvement in crop yields following crop rotations and intercropping. They found an increased yield in fields with no tillage under crop rotation. Many studies on crop yields under rotation have reported a positive impact on no-tillage practices, concurring with the findings of Karlen et al. (1991 & 1994a), who documented that crop rotations have the potential to usher greater yields across different soil fertility areas. However, it has to be noted that, in their study, Rusinamhodzi et al. (2011) reported that a combination of no-tillage and mulch did not affect crop yield compared to conventional tillage practices. They further articulated that there is a potential that after 10 years, the impact of no-tillage with mulch would be severely negative.

Soil Water Management

Less than 50% of the smallholder farmers in the study areas adopted soil water management (SWC) practices. Crop residue is vital for water conservation in the ground, as it covers the ground and reduces evaporation and erosion effects. In semi-central and Western Zimbabwean studies on smallholder farmers, 30% of the farmers use mulch where they have planting basins (Makuvaro et al., 2014). Soil moisture conservation is fundamental to yields and agricultural productivity under CA. Baudron et al. (2012) advanced in their study that cotton yields under CA were significantly lower in arid conditions than in traditional tillage approaches. However, smallholder farmers' low and slow adoption of water conservation methods has been reported in Zimbabwe's central and western parts (Nyamangara et al., 2013).

Furthermore, as Zimbabwe is categorized in V agroecological regions based on rainfall and soil fertility, smallholder farmers' effectiveness and applicability of all these CA technologies in their fields differ. For instance, some water conservation technologies are efficient in low rainfall seasons while subjected to waterlogging during the high rainfall seasons (Mutetwa & Kusangaya., 2016). Therefore, the risk of crop failure when there is waterlogging, 'kudhibha kwemunda' is high. On the other hand, CA technologies have proven to be impactful reported (Rusinamhodzi et al., 2011), especially that of soil moisture/water conservation (SWC) on crop yield in soils of poor drainage (clay soils), which are likely to arise in below-average rainfall regions. The same authors reported that maize yielded less in no-tillage practice short of rotation contrasted with conventional tillage practices however, higher when rotation was practised. Therefore, practicing zero tillage and crop rotations augmented the soil fertility structure to increase yields. Furthermore, Rusinamhodzi et al. (2011) verified, clearly in yield stability analysis results, that under extreme temperatures/drought or too much rainfall/flooding, no treatments can counter the consequences and impacts of these severe weather conditions.

2.4.2 Challenges in CA practice in Zimbabwe

As smallholder farmers' fields and households are heterogenous (Mupangwa et al., 2017), CA technologies are prescribed as 'one-size-fits-all' to smallholder farmers (Baudron et al., 2013). In addition, grazing issues, small landholding sizes, labour demand for weeding, and the manual system of planting basins due to draft power shortages among the smallholder farmers, have contributed to less adoption of CA (Mutsvangwa., 2020). This has been confirmed by (Mabiza & Manzungu., 2012) by reporting that the locally given name to CA is "Dhiga ufe," which means "dig and die". Different studies conducted in Zimbabwe show that labour demand for weeding and planting basins made CA unattractive (Mazvimavi & Twomlow., 2009; Mupangwa et al., 2017; Ndlovu et al., 2020). Challenges associated with mulch and legume seed availability in Zimbabwe and Zambia have also led to the partial adoption of CA (Baudron et al., 2007; Mazvimavi & Twomlow., 2009; Umar et al., 2011).

2.5 Case study 2: Conservation Agriculture as practiced in Zambia

Numerous organisations across the country have promoted CA in Zambia. Government ministries, agencies, and NGOs like the Zambian National Farmers Union (ZNFU) and Golden Valley Agricultural Research Trust (Gartner) have promoted CA among Zambian smallholder farmers. CA was introduced and promoted in Zambia as in other Sub-Saharan African (SSA) countries. (Gowing & Palmer., 2008) propagate that there was no convincing adoption of CA by SSA countries, including Zambia. However, they have also noted that Zambia recorded a small portion of adopters among their smallholder farmers population.

On the other hand, Haggblade and Tembo (2003) say that Zambia's smallholder farmers have embraced CA more, with over 70 000 or 10% (Haggblade & Tembo., 2003; Baudron et al., 2005) of all Zambian rural farmers said to have adopted the technologies successfully by the year 2003. It has been reported that in 2006 the number of smallholder farmers who adopted the recommended CA practices rose to between 125 000 and 175 000 (CFU. 2006). Other research studies also document that in Zambia, "estimates were that 35,000 farmers had adopted improved reduced tillage, 25,000 conservation tillage, and 18,000 conservation farming as a whole." (Haggblade & Tembo., 2003). CA positive impacts on crop yield are primarily experienced in arid and semi-arid agro-ecological zones with less than 1000mm mean annual rainfall (Gatere et al., 2011).

On the other hand, intensive traditional tillage, bare soil with no vegetation cover – dead or alive- and burning off residue to reduce diseases and pests, increase fertility, and weed obliteration by local rural farmers was a dominant practice across the Zambian agricultural smallholder farming. Thus, adoption is at a minimum in these areas, and those adopting the

CA technologies, do not apply CA to all their plots (Umar et al., 2011). Hence, CA adoption in Zambia has remained low but ranked better or as a 'success story' (Baudron et al., 2007) compared to other SSA countries. Furthermore, it has been stated that smallholder farmers usually perceive CA as "a complement to their regular cropping system rather than an alternative to it." and they do not practice it on all their farms (Baudron et al., 2007; Thierfelder et al., 2013; Umar et al., 2011). Rural farmers in Zambia are using both CA and conventional farming in different fields. The vulnerability and susceptibility of CA to the vagaries of climate and market failures are the major factors driving smallholder farmers into partial adoption of CA (Umar., 2014). Below, I describe some of the CA technologies adopted and how they have impacted smallholders' yields in Zambia. I have looked at tillage practices and planting, cover crops and mulch, and impact yields and harvests.

Tillage and Planting

Conventional agriculture, which mainly involves breaking down the soil to plant and reduce weeds on the farm, has been the primary farming method in Zambia. Conservation tillage was introduced in Zambia to discourage soil disturbance and increase soil organic matter by maintaining growing crops, dead crops- crop residue, crop rotation, and herbicides to lessen weed invasion. (Baudron et al., 2007) states that all tillage system levels in Zambia shifted from conventional tillage to conservation tillage. In their study in Southern Zambia, the same authors noted that CA practices from minimum tillage to ripping to actual no-tillage are evident among smallholder farmers. The use of homemade planting basins and ripping – by animal draught power by farmers with animals or access to it- is promoted under CA to reduce tillage. However, in their study, Gatere et al. (2013) purported that CA benefits accrued through water-harvesting using basins and waterlogging effects have severely depressed agricultural yield under above-average rainfall areas.

The Zambian National Farmers Union (ZNFU) initiated the CA no-till approach in 1995, hinging on the success and experience of Zimbabwe's Brian Oldrieve CA practices. They reported that basins are used for planting crops deposited simultaneously with manure, fertilizer, and other inputs. In the study conducted by Baudron et al. (2007) in the South of Zambia, the hand hoeing method is widely used in the dry season to make 'permanent' planting basins. The soil's organic structure remains intact by digging the planting basins using a hoe. More than 15 700 basins are dug per hectare under CA tillage practice and planted in areas such as Choma and Monze Southern Zambia (ibid). As stipulated by CA tenets, the basin dug in one season could be used the following season, thereby reducing labour demand (Thierfelder et al., 2013; Thierfelder et al., 2010). However, due to the free grazing- cattle roaming around after harvests- the basins will end up disappearing (Mashavakure et al., 2019).

A study by Umar (2014) in Southern, Central, and Eastern parts of Zambia, showed that planting basins and ripping are some of the CA methods employed. However, basins are on a small piece of land (25%) compared to ripping (88%), as they are food security strategies among smallholder farmers. In Zambia's Central, Eastern, and Southern provinces, a combined agricultural system of Conservation Agriculture and conventional tillage is widespread (Umar et al., 2011). However, Corbeels et al. (2014b) reported that yields of many crops grown under CA planting basins are lower under arid and drier conditions.

Cover crops and Mulch

In their study, Thierfelder et al. (2014) reported that crop residue is as important as crop rotation in causing higher yields under CA practice. Permanent soil cover or a minimum of 30% ground cover is advised to be practiced on any land under CA (Thierfelder et al., 2013; Umar., 2014; Umar et al., 2011). Maize, cotton, soybeans, and cowpeas constitute some of the crops grown by smallholder farmers in Zambia (Thierfelder & Wall., 2009). Thus, the southern half of Zambia is called the maize belt (Umar., 2014). Cover crops intercropped with main crops include groundnut, cowpea, sweet potato, and cassava. In addition, cash crops such as sunflowers, soybeans, cotton, tobacco, and horticultural crops are cultivated (Baudron et al., 2007). Crop rotation is encouraged under CA. However, according to the study by (Thierfelder et al., 2013) in Zambia's Southern and Eastern provinces, the efficacy of such a strategy in controlling pests and diseases is not guaranteed.

Crop residue is fundamental in providing ground cover, which enables surface organic matter, runoff and soil erosion reduction, and improvement of soil infiltration capacity. However, in their study in Zambia's Central and Southern provinces, Umar and colleagues (2011) discovered that crop residues were not retained in the fields and were routinely fed to livestock (Umar et al., 2011). In Zambia, many areas are turned into communal grazing lands after harvest. It is estimated that "some 15,000 farmers were spontaneous adopters, while 60,000 practiced conservation farming" as a condition for receiving incentives, and when the projects and support stop, they revert to conventional practices (Baudron et al., 2007; Nyanga et al., 2011; Unit., 2006). These are some of the dimensions that have led to the slow and low uptake of CA in Zambia.

Crop Yields and Harvests

A study conducted by Umar in Zambia has documented a positive impact of CA on yields reported on smallholder farms (Thierfelder., 2010; Umar., 2011; Thierfelder., 2012; Thierfelder., 2013; Umar., 2014). Umar (2013) noted that a combination of CA principles' applications yields an increase. The use of basin, precise input application, and early planting ensure higher yields, while ploughing and hand hoeing lead to loss of crop yields when rainfall is below average (Umar., 2011). Rockstrom et al. (2008) and (Giller et al., 2009) concurred with Umar (2014) in their study that minimum tillage practices increased water productivity and crop production output, even when little or no mulch through crop residues was done (Umar., 2014). However, in most smallholder societies characterized by uncertainties, adoption of CA has remained low (deposit knowing the accrued economic and agronomic benefits associated with CA) due to a preference to diversify tillage methods which are believed to provide safety nets or stable yields (Umar., 2014). Crop yields under CA improve primarily in areas with average and less rainfall, while profits suffer in waterlogged regions where rain is above average (Giller., 2009; Giller., 2015).

Furthermore, Thierfelder and colleagues noted that maize yields increased by up to 78% when direct-seeded and rotated with cowpea, seeded with a dibble stick after four cropping seasons (Thierfelder., 2013). However, it has been noted that in the Malende district, the comparison between conservation and conventional tillage impacts on maize crop yields are not different in three years. The study documents the articulations by some scholars that CA could lead to low yields in the first few years. Moreover, Thierfelder et al. (2013) reported that yield profits under CA treatment increased more than conventional tillage practices in the fourth season. The expected effects of CA are significant where moisture and the production capacity of the soil are limiting factors.

Challenges to CA Adoption in Zambia

There are many challenges to adopting CA by smallholder farmers in Zambia. Households prioritize maize cultivation which, when there is a shortage of labour, would be difficult to grow other crops in appropriate fields, thus impacting the crop rotation system of CA (Baudron et al., 2007). The belief by farmers in the southern province that rotation is only necessary if yields begin to decline also puts CA uptake to a halt in many areas, including Monze and Choma in southern Zambia. Nolin and Von Essen (2005) noted that some rural farmers who heed the call not to burn crop residue prefer to carry it and feed their cattle rather than leave it as soil cover. This is cemented by the fact that in southern Zambia, cattle/livestock are precious- food security and drought risk averters are prioritised.

2.6 Case study 3: Conservation Agriculture as practiced in Tanzania

The Tanzania government recognized CA in the late 1980s to curb the effects of the traditional farming practices that were causing land degradation- soil erosion, poor infiltration and nutrients, and poor nitrogen-fixing capacity, among other things, pushed the state to promote CA. As a result, a coalition of government, NGOs, and the private sector has been promoting CA in the Arumeru district and the whole of Tanzania. A study conducted in Tanzania by (Shetto & Owenya., 2007) observes that partial adoption of CA technologies is what most farmers are practising. It is mainly due to its feasibility in their respective situations, which are defined by the difference in topology, soil type, and the available indigenous knowledge (Mkonda & He., 2017). Several drivers for partial or poor adoption in other parts have been cited, however, in areas such as Arusha, Runyara, and Ruvhuma, CA, adoption has been well embraced (Ibid). To mention a few, agronomic practices such as mulching, crop rotation, terraces, no-tillage, and agroforestry are Tanzania's most applicable soil organic management practices (Mkonda & He., 2017).

CA adoption in Tanzania is more in places that host most CA organizations and implemented projects (Shetto & Owenya., 2007). Agronomic practices such as mulching, crop rotation, terraces, no-tillage, and agroforestry, to mention a few are the most applicable soil organic management practices in Tanzania representing conservation agriculture (Mkonda & He., 2017). Where adoption is low, various stakeholders such as the agricultural extension officers, politicians among others, believe that “agriculture without tillage is utopian” and therefore, they “emphasize the use of tractors and ox plough to till the soil” (Mkonda & He., 2017).

In the north and central Tanzania, CA adoption has been said to be better than in other parts of the country (Branca et al., 2013). However, most smallholder farmers in Tanzania have challenges upholding all the CA principles – no/reduced tillage, crop residue for soil cover, crop rotation/ intercropping, and herbicides used for weeding control. It is therefore imperative to grasp and understand what the literature says about the dominant farming systems and patterns in Tanzania. CA has been reported to have increased the crop yield, grain size, and quality of the harvest in Tanzania, thereby pulling many farmers out of poverty. In Tanzania, results under CA were higher (from 1.25t/ha in 2004 to 7.0t/ha in the year 2009) primarily in those fields where intercropping of maize with cover crops, improved soil conservation, and water management was recorded, however, in 5 years (Owenya et al., 2011).

Conservation agriculture operates in different forms and principles, such as terraces or ridges due to some parts of Tanzania's hilly nature and slopy terrain. Minimum tillage, cover cropping, cropping system, and large pits and intercropping, especially legume intercropping of sweet beans and lablabs, are used in Tanzania (Mkonda & He., 2017). Below, I describe some of the CA technologies adopted and how they have impacted the smallholders’ yields in Tanzania. I have looked at local tillage systems employed practices and planting, cover crop and mulch, impact yields, and soil fertility management.

Tillage system

The study by (Kahimba et al., 2014) in northern and central Tanzania illustrates that CA is practiced on different levels, using various methods across the regions. Small-scale farmers use equipment such as jab planters, hand hoes, rippers, slashing, etc. In Dodoma -Central Tanzania, conservation tillage is fuelled by the availability of oxen among farmers to use ox-drawn rippers (Kahimba et al., 2014). ‘Large pits’ are used for planting in Dodoma, and 23.7% of the farmers in their study were practicing zero tillage, ripping, and minimum tillage (ibid). Mkonda and He (2017) also found out in their research in both central and northern Tanzania that terracing and conservation tillage is used in Arusha and Dodoma, respectively. They postulate that the ‘Matengo pits’ are also used in the Ruvhuma region. In contrast, planting basins are used in the Southern Agricultural Growth Corridor (SAGCOT) in the southern highlands of Tanzania. Furthermore, they articulated that about 60% of the farmers in Arusha- the northern part- are using plant basins to help keep soil moisture and organic fertility.

Crop residue and Fertility management

Crop residues are left on the farm after harvest to allow soil decomposition and fertilization (Kimaro et al., 2016). Owenya et al. (2011) reported that farmers in Mwangaza, Rhotia village, and Karatu districts of Tanzania are no longer applying inorganic fertilizers in their farms due to good soil management practices through zero herbicide application during land preparation, increased use of cover crops, and use of traditional herbs in the fields (Owenya et al., 2011). Most mulch is from maize stover, bean straw, banana leaves, coffee leaves, and soybean residue (Shetto & Owenya., 2007). Due to the nature of the terrain in northern Tanzania- Arusha district and Karatu- mulching and 'jaruba' are less adopted however, cover crops are used by 16.6% of the farmers in the study (Kahimba et al., 2014). Owenya et al. (2011) reported that contour bunds are used for water retention and harvesting, and plant cover crops such

Crop rotation and Intercropping

The intercropping practice has been done in Tanzania's Arusha regions, in districts such as Arumeru and Karatu (Shetto & Owenya., 2007). A study conducted in the Rhotia, Karatu, and Mwangaza districts of Tanzania, observed that crop rotation is practiced together with wheat and pigeon pea (Owenya et al., 2011). Maize is the staple crop intercropped with beans or pigeon peas in the north (Muguza et al., 2007). Lablab is also widely used for intercropping. More than 60% of smallholder farmers in the Karatu district practice intercropping with maize and pigeon pea (ibid), however, some use maize and pumpkin for diversification and intensification. In Dodoma, sorghum is the main staple, while in the Ruvhuma region, maize is intercropped with lablab (Mkonda & He., 2017). In what they call the "transition period," which is the first years (3-5 years) of switching from conventional to conservation farming, (Shetto & Owenya., 2007) advance that it is when weed control is very problematic among smallholder farmers. Weeding has been reported as a challenge to CA's reduced tillage practice. Labour shortages and arduous labour demands of basins, reduced tillage, weeding, and other techniques.

2.7 Lessons from the CA literature

The promotion of CA in Zimbabwe, Zambia, and Tanzania was done by different organisations such as Brian Oldrieve's church (Oldrieve., 1993), Zambia National Farmers Union, and NGOs, respectively, These organisations worked in tandem and partnership with the respective governments. The partnerships and other stakeholders have vehemently promoted CA adoption and practice across these countries. CA has been promoted in consideration of environmental and local conditions influencing adoption by smallholder farmers. Smallholder farmers have demonstrated the capacity to continue with CA adoption where the project promoters initially set up projects, for example in Ameru districts. In addition, CA has proven sustainable or to be adopted more where there are more government, NGOs, and other stakeholders' support.

Input availability and access are of fundamental importance to the evolvement of CA adoption by smallholders. In places where farmers had access to seeds for cover crops, the CA principle of permanent soil cover was attained by many farmers, for example, in Tanzania districts.

Furthermore, mulch and crop rotation have aided in eliminating crop pests and diseases and helped to conserve soil moisture content. The practice of soil water management has greatly augmented yields. More so, the practice of CA and the benefits accrued are contingent on the climatic factors of the place. Rusinamhodzi (2011) reported more crop yields in areas with less average rainfall. The implementation and further practice of CA in Malawi could derive these lessons from other countries to counter the constraints to CA adoption. In some other cases, such as studies conducted in southern Zambia by Thierfelder and associates (2013), crop rotations and intercropping of maize and cowpea under the direct-seeding method of no-tillage have ensured an increase of 78% in crop yields after a minimum of three seasons.

2.8 Case Study 4. Conservation Agriculture as practiced in Malawi

A Nation of Farmers

Malawi is a country whose mainstay is hinged on rain-fed agriculture. However, the irrigation infrastructure to enhance agricultural production in that part of the continent has mainly remained underdeveloped (Wiyo et al., 2000). Accordingly, the Malawian economy is pivoted to agriculture to improve food security and nutrition. The agricultural sector in Malawi bifurcates into two farming categories: commercial and subsistence farming. Malawi's main commercial cash crops are tea, cotton, coffee, tobacco, sugar, and groundnuts. Maize is the widely grown subsistence staple crop -accounting for 90% of the national cropping area (Gilbert et al., 2013), occupying 75-85% of land portions in smallholder farmers in Malawi (Ito et al., 2007). Malawi is heavily dependent on maize crops, most grown by over 90% of farm households. Kakota and associates have reported that fifty percent of the calorie intake by Malawi rural farmers comes from maize (Kakota et al., 2015).

Moreover, as manufacturing contributes 11 percent of Malawi's GDP, agriculture generates 83% of the country's foreign exchange earnings (Chinsinga & O'Brien., 2008). As a result, Malawians' annual maize consumption increased to 150 kg (which approximates more than two-thirds of their caloric intake), the world's largest per capita consumption of maize (Gilbert et al., 2013). In addition, other crops grown for both subsistence and commercial include cassava, bananas, sorghum, rice, and sweet potatoes.

The agricultural sector in Malawi employs more than 80 percent of the country's overall labour force and represents approximately 37% of the gross domestic product (GDP) (Maher et al., 2015; Thierfelder et al., 2013a; Thierfelder et al., 2013). Smallholder farmers in Malawi produce approximately 70 percent of the total agricultural output in Malawi. Around 80% of Malawi's population is rural-based and thrives on rain-fed agriculture (Fisher et al., 2018; Maher et al., 2015). Smallholder farmers commonly occupy 0.2ha of land in the South part of the country (with a high population density) and 0.3ha in the Northern region (with a small population). Malawi is one of the poorest countries and Donor-Aid dependent because, according to the United Nations Human Development and Poverty Index rankings, Malawi occupies the position of 170 out of 185 countries in adverse poverty (Maher et al., 2015).

Significant strides have been made to ensure poverty alleviation owing to dry and semi-arid areas in Malawi, however, it has not been easy to note the determinants of vulnerabilities to food insecurity. The Food and Agriculture Organization (FAO.) of the United Nations has shown an approximate increased number of famished people increased from 848 million to 923 million from 2003/2005 to 2007 (Kakota et al., 2015) and hungry people from 812 million in 2017 up to 820 million in 2018 (Boliko., 2019). It has mainly owing to the food price crisis, poverty, and climate factors (Chinsinga & O'Brien., 2008). In Malawi, many people affected live in rural areas (Pinstrup-Andersen., 2009). Poor agricultural crop yields across numerous seasons in Malawi attest to this poverty and poor livelihoods. The majority of the population, approximately 55% in Malawi, lives below the $1 per day poverty datum line (Langyintuo & Mungoma., 2008), and at least 22% live under $0.26 per day and are classified as "ultra-poor" (Chinsinga & O'Brien., 2008; Gilbert et al., 2013). Estimates suggest that 50 % of the rural population runs out of food for about 4–6 months before the next harvest, and 40% cannot ensure its basic calorific needs (Pankomera et al., 2009). According to the FAO (2011), an achievement of a 20% to 30% agricultural increase in low-income countries would have been realised had women accessed the same resources equally as men do.

It is paramount to note that Malawi has achieved national food security through the Farm Input Subsidy Programme from 2005 to 2008 (Chinsinga & O'Brien., 2008). Moreover, Malawi's agricultural boom turned the country from a net importer to a net exporter of maize to Zimbabwe, Zambia, and other southern African nations (Chinsinga & O'Brien., 2008). How was that feat achieved? What went wrong following the Input Subsidy Programme? What expunged Malawi's capability to continue being the net exporter trajectory? These are fundamental questions to the famishing scenario confronting Malawi today.

There is an indication of declining soil organic matter due to the continuous overgrowing of maize. As a traditional farming technique by rural folks, conventional agriculture has been de-campaigned for harming the soil through tillage, ploughing, ridging, and heavy weeding by manual or mechanical means (Bunderson et al., 2017). These practices have immense detriments on land and the environment, such as land degradation and adversely impacting soil structure and fertility. The monoculture approach to farming has depleted these smallholder farms' fertility and soil capacity. There is evidence of a 10 to 31% decline in mean organic carbon in three regions over 20 year period (Gilbert et al., 2013).

Consequently, breaking down the soil's organic structure resulted in poor and compromised agricultural productivity in smallholder farms in Malawi. As a result of 'tired' soils -lacking nutrients – hunger and starvation have been persistent in the country. For the past three decades, Malawi has undergone severe food crises in 1992, 1994, 1997/1998, and the most deadly ones- were in 20012002, and 2005 (Chinsinga & O'Brien., 2008). Northern Malawi has a small pastoral economic base. Agriculture is the mainstay; however, cattle play a crucial part in the region's food security. Additionally, climate change vagaries and stresses vectoring through droughts, floods, extreme temperatures, and unreliable rainfall regimes contributed to the shrinking agricultural productivity in many rural parts of Malawi, resulting in severe food insecurities.

Therefore, the prescription of Conservation Agriculture as a 'basket' of technologies to promote reduced soil disturbance, soil fertility, permanent soil cover, and crop associations has been encouraged to reverse land degradation and its adverse effects on the environment, yields, and productivity, and to increase both men and women's participation in proper CA methods.

Poor farming methods and lack of proper land management techniques have all impacted the agricultural productivity of the areas (Bunderson et al., 2017; Bouwman., 2018; Andersson & Giller., 2021). Land size has been an issue for smallholder farmers in increasing productivity. Malawi's burgeoning population- density in Malawi is 93 people per km^2- has ushered in shrinking idle periods, declining food production, and decreasing per capita (Gilbert et al., 2013). O'Brien has propounded that "lack of alternative livelihoods, combined with the small size of plots, compel farmers to cultivate maize on the same land year after year. Over-cultivation has reduced soil fertility" (Chinsinga & O'Brien., 2008).

The study looks at the prospects of bailing out smallholder farmers from the shackles of poverty. Smallholder farmers' dilemma begins at different farming stages. Some encounter difficulties with planting, weeding period (with diseases and pests), harvesting, markets, and storage difficulties. Food security is (FAO., 2011) "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" (Jones., 2015).

2.8.1 Inception of Conservation Agriculture in Malawi

Bouwman (2017) described the inception of CA and how it was practiced and implemented in Malawi in her paper "Can Conservation Agriculture transform Malawi?" She noted that minimum tillage was introduced in the late 1990 decade, as an urgent matter to the much-focused quagmire of environmental degradation through soil erosion (Bouwman., 2017).

However, the minimum tillage project was finalised in 2003, and in areas such as Lilongwe, there was little or no adoption of the project after it ended (Mataka., 2003). Therefore, numerous lessons were learned from this first phase of CA adoption. Ngwira et al. (2013) stated that "these past efforts concentrated on no-till and residue retention only, without considering the part played by crop rotation or intercrop association."

2.8.2 Current Conservation Agriculture Practice in Malawi

Following several trials and errors from the projects that introduced CA's practice and adoption in Malawi, numerous improvements and adjustments were made and are still being made to accommodate and reach the maxim of CA success in Malawi (Banda., 1995; Banda., 2002). In a study by Bouwman (2017) in Zidyana and Mwansambo in Malawi, the means to achieve some principles of CA differed, for example, the crop residue on farmland. In this study, some crop residues are said to have been taken from other areas and deposited onto other farms. However, currently, CA in Malawi has discouraged the use of a hoe (even for ridging or breaking down old ridges that were made), while keeping crop residues for permanent soil cover purposes (Bouwman., 2017), and intercropping with maize, legumes and/ groundnuts are advised to the smallholder farmers (Bunderson et al., 2008; Andersson., 2014). Smallholder farmers practicing CA in many parts of Malawi employ the wooden dibble stick, which aims to punch only a hole in the ground to plant the seeds, disturbing the soil as little as possible (Bunderson et al., 2017).

The six-year study (2005-2011) by Ngwira et al. (2013) in 2 central and southern Malawi districts of Balaka and Nkhotakota documented how CA is practiced and evolving. They said that a critical CA component in Malawi would be the 'rotation' principle (ibid). The reason is typical farmers' land holdings, which are too little to accommodate crop rotation practice but rather engage in intercropping systems to attain diversification. Ngwira et al. (2013) purport that some crops, such as legumes, are not growing because of farmers' fear of growing them without having a ready market. This has drawbacks to the advancement of intercropping or crop rotation practices, which fulfil CA's commandments. Herbicides use under CA, in most instances, the use of herbicides is promoted within the CA package to control weeds, which become a nuisance, especially in the initial years (Ngwira et al., 2013).

Bunderson et al. (2017) have reported that in Malawi more potential benefits are accruing from CA adoption. For example, the enrichment of soil fertility structure and increased soil water retention capacity due to adequate mulch have resulted in sustainable crop production and high yields (Jumbe & Nyambose., 2016). Thus, Farooq et al. (2011) reported that in Malawi and SSA, CA's impact on yields is primarily greater than conventional agricultural techniques where yearly precipitation was not more than 560 mm.

Tillage and Mulch management

Minimum or zero soil tillage together with a surface mulch aids in soil moisture retention while reducing evaporation (Giller., 2009). In arid and semi-arid conditions, soil moisture improvement enables the roots of crops to go deeper (Giller., 2009; Giller., 2015). Hussain et al. (1999) observed that the combination of tillage and mulch management has the potential to substantially improve crop yields and soil conditions in the semi-arid tropics. Corbels et al. (2014) concluded that mulch is a major factor in influencing the performance of CA systems. Hobbs and Govaerts (2010) identify CA as a climate change adaptation strategy because improved soil quality and nutrient cycling are expected to strengthen crop growth and increase crop resilience to variable rainfall and higher temperatures.

Weed and Water management

Branca et al. (2013) reported that integrated nutrients, agronomy, and water management practices increased crop yields in humid areas more effectively than in dry conditions. In contrast, the mean yield increase in their study was recorded in tillage and agroforestry practices that were embedded in dry areas conditions (ibid). Thus, water management and conservation technologies are fundamental to crop productivity and yield in humid and arid conditions.

Bouwman et al (2021), explained the importance of herbicides in weed management for farmers practicing CA technologies fundamentally that of zero tillage as weeds tends to sprout. In their study in Mwansambo and Zidyana, households who used herbicides hired labour substantially less than before. Those hiring labour for banking ridges or weeding -as they are both weeding techniques by smallholder farmers reportedly admitted to a 65% reduction of the labour hired. In Ethiopia and Mali, Tamru et al. (2017) and Haggblade et al.

(2017) found similar reductions (50% and 70–80%) in labour demand. Thus, herbicides use reduces the demands on labour required for weeding and bank ridging, thereby lowering casual labour/ganyu work for other households that rely on it.

2.9 Challenges to Conservation Agriculture Adoption

This section covers the factors that affect CA adoption by smallholder farmers. It includes factors affecting CA adoption such as inconsistent and conflicting CA messages, lack of information and training, lack of inputs and herbicides, labour constraints and time consumption, lack of markets and returns on investments, competing uses of crop residue, farmer's perception and mindset, approaches by project promoters among others.

CA promotion across the sub-Saharan African continent has been ongoing for over two decades. However, adoption levels have remained low and slow among smallholder farmers despite various efforts by numerous organizations to expand it. The feasibility and application of CA in local contexts and different environmental and climatic conditions by potential users in Malawi and SSA have been raised (Sumberg., 2005; Mkandawire., 1986; Bouwman., 2017; Bouwman et al., 2020). CA is the best fit for the sustainable intensification of agriculture and food security enhancement (Baudron et al., 2007; Derpsch., 2008; Giller et al., 2009). It is also vital to comprehend the differences in the adoption practices reported on trial plots and demonstration plots (Mutsvangwa., 2020; Bunderson et al., 2017).

Why is there Low Adoption by Farmers?

Many smallholder farmers in Malawi lack proper training on CA and an understanding of the concept (Bunderson et al., 2017). The information on CA being delivered to the farmers by field advisors and extension officers in Malawi are 'misguiding and confusing, thereby leading to less adoption (Bunderson et al., 2017). The lack of inputs has been cited as a considerable constraint to CA adoption, according to a study conducted by Ngwira (2014) in Malawi. The role of inputs and nutrients in enriching the soil has been noted as decisive in reaping benefits from CA (Ngwira., 2014). Their study results, the practice of CA without fertilizers provides limited benefits- low and inconsistent yields- to farmers. For example, maize (Zea mays) yields were 11% and 18% lower with no-tillage without mulch than with CT and no tillage with mulch, respectively (Ngwira., 2014).

CA allows the reduction of the time and labour expended, particularly at peak demand, on such activities as land preparation and planting (FAO, 2010). The labour demands on land preparation are repeatedly acknowledged to decrease with reduced tillage. It was accurate; however, the area under CA (0.2 ha) has not increased since then (Andersson & D'Souza., 2014). Digging planting basins and weeding thrice or four times (Nyamangara et al., 2013) has placed a cumbersome burden on smallholders. Similarly, studies in Zimbabwe demonstrated that increased manual labour for weeding and planting basin preparation had raised concerns with many smallholder farmers (Rusinamhodzi., 2015; Marongwe et al., 2011).

Input and herbicides costs have not made adoption easier among smallholders. CA is an inappropriate farming system for a bulk of poor and resource-limited smallholders (Giller et al., 2009). Herbicides application has been noted to replace labour demand for weeding. However, the prices of herbicides have made them unaffordable to poor farmers. Bouwman et al. (2021) reported that "development interventions need to be inclusive – rather than assuming that poorer households are beyond help as some did in Zidyana and Mwansambo study areas." In Malawi, herbicide application has worked for the well-off farmers while impoverishing the poor who depended on 'ganyu' off-farm activity – weeding other farmers' fields (Bouwman., 2017).

Smallholder farmers under CA produce both for consumption and profits- through sales. The absence of viable, readily available access to markets for their legumes and main crops has dented the CA adoption capacity in many African countries (Andersson & D'Souza., 2014; Thierfelder et al., 2013; Thierfelder et al., 2013). For example, farmers in Zimbabwe's semi-arid areas have raised concerns about the lack of a market for crops such as millet and sorghum (Mutsvangwa., 2020). In Zimbabwe and Malawi, a lack of needs and unavailability of seeds has led to less crop diversity and rotation (Mazvimavi & Twomlow., 2009).

The benefits of CA are said to materialize arguably from the second year of implementation. Adoption benefits on yield gains are season and agro-ecology-specific (Andersson & D'Souza., 2014; Thierfelder et al., 2013; Thierfelder et al., 2013). Farmers who use basins and ridge furrows in Malawi have not increased their cultivated land area due to the amount of labour they put against low gains (Bunderson et al., 2017). In Kenya, smallholders have also vacillated between massive investments in inputs and equipment put in to adopt CA versus the lag time to the accrual of benefits, which is long and discouraging for small-scale farmers (Mugandani & Mafongoya., 2019).

Various studies and reports have noted the paradoxes surrounding mulch availability in sub-Saharan African countries with a combination of both pastoralism and agriculture systems (Hove & Gweme., 2018; Andersson & D'Souza., 2014). As a principle of CA, it is vital to have at least 30% of the ground cover in crop residue. Due to low biomass production in Zambia and other African countries, crop residue is supplementary to livestock feed (Umar et al., 2011). The absence of communal grazing lands and bulwarks or fences on smallholders' fields has become a constraint as livestock graze freely after harvest. In Zimbabwe, there is a lack of control over livestock that grazes freely on the pasture after yields have consequently resulted in a shortage of ground cover (Derpsch., 2008; Mazvimavi et al., 2010). Other farmers have used their income to ensure their fields are fenced to protect mulch from livestock. As a result, farmers could not attain the 30% ground cover threshold from their maize-dominated agricultural fields (Andersson & D'Souza., 2014).

Malawi has been argued to have few cattle, which lessens the demand for crop residue as livestock feed (Thierfelder et al., 2013). Although in some cases, farmers sell crop residue for income generation (Maher et al., 2015), in other areas, traditional practices and cultural activities of burning crop residue for different purposes such as land clearing, mice hunting (by community people), and pest control measures have overtaken CA tenets (Giller et al., 2009). The labour constraints have been aggravated by the accuracy needed in stipulated depths and distances in-between basins and rows (Beuchelt & Badstue., 2013; Giller et al., 2009). In Zambia and Zimbabwe, women have complained of the heaviness of the Chaka hoe's weight (4-5kg) (Hove & Gweme., 2018) over the traditional hand hoe for their back, as they should lift it to strike impact on the hard soil pan when making basins (Nyanga et al., 2012).

Project promoter organisations have prescribed CA as a one-size-fits-all, which has proved detrimental to CA adoption in many countries. CA may not be profitable to all categories of farmers (Giller et al., 2009) and should not be taken as a panacea to all agricultural production constraints (Mugandani & Mafongoya., 2019) site-specific. Project promoters who put a blanket application of CA on all smallholders will 'not work' but somewhat reduce the adoption capacity of CA (Marongwe et al., 2011; Derpsch., 2008; Erenstein., 2003). One size fits all emanates from the setup of demonstration plots or supervised projects, which lacks social and contextual relevance of practical societies (which overrides it in the post-project period), and factors outside supervised projects (Twomlow et al., 2008; Umar et al., 2011).

NGOs and other promoters have been said to have compromised the work of the Agritex department in Zimbabwe when promoting CA, which has led to dis-adoption. Mutsvangwa (2020) propagates that CA promoters use input packs of fertilizers to recruit smallholder farmers in other parts of Zimbabwe – Gwanda and Insiza. AGRITEX has lamented that it cannot offer inputs in the same fashion as the donors or NGOs. It has led to low turnout at their training meetings and workshops by smallholder farmers who are not motivated by non-incentive discussions of the Agritex department. At worst, the lack of continuous supply of lucrative inputs led to dis-adoption by other households. According to a study in 15 districts in Zimbabwe, 11% of the farmers practicing CA dis-adopted it in the cropping season in areas where NGOs and donors withdrew support of inputs and other resources (Mazvimavi et al., 2010).

2.10 Gaps in the Literature on Conservation Agriculture

Most of the literature has covered the role of CA on soil fertility, maize grain yield, soil moisture quantity, combinations of crop rotations and adoption of CA, and challenges to effective implementation of the technology in South and central Malawi (Bell et al., 2018; Bouwman., 2017; Bouwman et al., 2020; Bunderson et al., 2017; Mloza-Banda., 1995; Ngwira et al., 2014; Nyambose & Jumbe., 2013; Phiri., 2016; Sosola et al., 2011; Thierfelder et al., 2013). However, little has been done in Malawi to understand the impact of each CA technology on specific crops like maize, Irish potato, groundnuts, soybeans, beans, sweet potatoes, and vegetables that make the diet and staple (maize) of Malawi. It is noteworthy that some experimental work/studies have looked at the effects of CA-no tillage impact on maize (Banda., 2003). Many of these works have used maize crops to analyse the effects of CA components such as soil water conservation.

In addition, the literature has not been able to show the individual impact of each of the CA technology on a specific crop. The existing literature is shy of the studies of CA technologies' effects on crop yield, specifically in the Dowa district of Malawi. Hence, this study looks at the impact of each of CA's technologies on seven different crops grown by most smallholder farmers in Malawi. It is, therefore, the aim of this study to bring to the fore the impact of each of the CA technologies (mulching, zero tillage, and cropping system) on specific crops' yields and income, such as maize, Irish potato, groundnuts, soybeans, beans, sweet potatoes, and vegetables.

Chapter 3

3. Methods and Methodology

This chapter discusses the data collection methods, sampling techniques, study design, research ethics, and the study sample. This chapter also includes the study methodology, data analysis and selected models.

3.1 Study design

The study used a cross-sectional design using quantitative research methodology.
The data was collected from five districts in Malawi in the TRANSFORM (inception phase) project from 05 October 2021 to November 2021. However, due to data limitations, the current study's analysis was focused on one district named Dowa to assess the impact of CA-associated practices on crop yields, income, and the role of livestock in improving the smallholders' income.

This survey questionnaire was focused on the following main topics: the type of irrigation equipment used, cultivated land size, types of crops grown, total harvests, marketplace availability, and livestock owned and sold. The survey data includes crops such as cereal crops- maize, sorghum; legumes -beans, soybeans, groundnuts; root and tuber crops-sweet potatoes, Irish potatoes, and vegetables. Most smallholders grow the crops mentioned above for subsistence and selling. Maize is the staple crop for Malawi, and it is grown by 90% of the population. As noted by Golbert et al. (2002) that, "Malawians consume over 150 kg maize yr-1, (which constitutes greater than two-thirds of their caloric consumption), the largest per capita consumption of maize in the world", this confirms the the dominance of maize production in the country.

3.2 Sampling

A total of 1818 farmers participated in the study from the Transform programme. The study used convenience sampling on all the registered TRANSFORM farmers. However, from Dowa district, a total of 350 respondents' response was recorded. **KoBo Software**[7] to upload, collect and manage household data collection was used. This software is versatile and

[7] It is open access software used regularly by the NCA and NCA staff is well trained in using this software for survey conduction.

straightforward to use and can easily be connected to the server to manage and report data as it is being collected.

The consultants ensured that XLS forms were carefully authored and validated to ensure precision and the highest accuracy of data collected and appropriate logic, restrictions, and internal triangulations. The pre-programmed questionnaire was loaded onto the tablets for data collection, and the enumerators were instructed to upload the data to the server. The data was collected by TRANSFORM consortium field staff that is well trained in the survey conduction using KoBo software.

3.3 Research Limitations

The Covid 19 pandemic compounded the data collection process. The research was planned to take place in the autumn of 2020, with the research design and methodology all in place however, due to the Covid pandemic, travel restrictions were put in place, making it impossible to travel. Different fieldwork arrangements of up to three times were made but could not materialise due to Covid restrictions. Furthermore, fieldwork attempts were made until 2022 but to no avail. Hence, the study resorted to the extensive survey data collected by the TRANSFORM consortium from October 2021 to November 2021.

3.6 Data Analysis

The data were analysed using the SPSS software. In addition, descriptive statistics to report the participant's characteristics and the techniques of CA technologies were used. Gross margin analysis was done on the selected commodities with respect to the smallholder with and without practicing CA technologies.

3.6.1 Descriptive statistics

Descriptive statistics were employed to report the distributions in the study population. Contingency tables were constructed to describe the characteristics of the participants, including the age of respondents in different districts in the study, crops grown, technologies practiced, and household head's education. Analysis of Variance (Anova) was used to determine the correlation and effect of CA associate technologies on the smallholder’s income from different crops under study.

3.7 Ethics

Ethical considerations were adhered to during the study. Before each interview, either at the household or community level, there was a brief introduction about the research purpose, and the team sought consent from the survey participants. Similarly, participants were assured of confidentiality and that the information being collected would only be used for the survey and nothing more. Interviewers were also neutral, and enumerators were trained to respect the respondents' dignity and culture.

Adherence to GDPR guidelines on personal data processing was also made. For example, one of the ways to protect the respondent's identity was to remove the identification of the respondent by name. In addition, the TRANSFORM consortium was/is committed to protecting personal data against "unauthorized or unlawful processing," as well as accidental loss or damage.

Chapter 4

4. Results

4.0. Data and descriptive statistics

Our survey was based on the Transform programme annual data collected in 2021 in Central and Northern Malawi. A total of 1818 survey forms (questionnaire) were completed by the smallholders in 5 districts -Kasungu, Mzimba (Mzimba North and South), Mchinji, Rumphi, and Dowa, in Malawi. For the demographical presentation, the data from all 5 districts were used. However, for the CA practices, this analysis was limited to the Dowa district.

4.1. Descriptive statistics

Table 1. The demographical characteristics (age and district) of the surveyed smallholders across five districts in Malawi

Age	Dowa	Kasungu	Mchinji	Mzimba North	Mzimba South	Total
15-24	42	80	58	34	28	257
25-34	97	117	99	90	41	463
35-44	110	94	97	76	78	483
45-54	62	78	62	66	61	343
55+	39	35	47	78	60	271
Total	350	404	364	344	268	1818

Table 1 represents the age groups of the people and their districts. Kasungu has the most population (22%), while Mzimba South had the least, in the study. Close to 40% of the participants were youth in the range of 15 to 34 years in all the districts, with Kasungu having the most. Older people (55 years of age and above) amounted to 15% of the people in all the districts in this study.

Table 2. Distribution of surveyed smallholders with respect to their gender

Gender	Dowa	Kasungu	Mchinji	Mzimba North	Mzimba South	Rumphi	Total
Female	238	242	243	224	154	64	1165
Male	112	162	121	120	114	24	653
Total	350	404	364	344	268	88	1818

Table 2 above shows the gender and districts of the respondents. In this study, women constituted 64% of the participants across all the districts. In all the districts, more women participants were more than men, with Kasungu and Mchinji having the highest number of women. At least one in two respondents in Dowa, Mzimba south, Mchinji, and Rumphi were male.

Table 3. Number of surveyed smallholders using various types of irrigation methods for agriculture in 5 districts of Malawi

Irrigation type	Dowa	Kasungu	Mchinji	Mzimba	Rumphi	Total
Buckets	52	152	192	101	14	511
Treadle pump	1	3	4	10	1	19
Motorised pump	2	3	2	4	1	12
Solar pump	0	0	0	0	0	0
Lined Canal	1	1	1	0	11	14
Earth Canal	3	1	1	11	42	58
Sprinklers	0	0	0	0	0	0

Table 3 above shows the types of irrigation technologies practiced by smallholder farmers in study districts. The respondents were asked if they do irrigation and, if so, what/how they irrigate their farms. Irrigation options were given as, shown in the table above. The table shows that the bucket system is the most prevalent irrigation type among the smallholders, with almost two-thirds (n=511) of the participants using buckets. Almost a fifth (n=192) of the participants who use buckets are from the Mchinji district while Rumphi has the lowest number of people (n=14) who use buckets for irrigation purposes. Another point worth noting is that solar pumps and sprinklers are not embraced across the districts.

Table 4. The number of surveyed farmers selling their produce to various markets.

Selling points	Dowa	Kasungu	Mchinji	Mzimba	Rumphi	Total
Nearest Market	164	166	143	176	48	697
Home	166	50	52	160	39	467
Vendor/Middleman	314	357	310	366	54	1401
Private trader/formal market	20	3	8	16	9	56
Agro-dealers	31	28	37	27	6	129
ADMARC	31	29	10	150	29	249
NASFAM	1	18	9	14	2	44
Cooperatives	18	9	11	11	8	57

Table 4 shows where the smallholders sell their crop produce in their districts. Over 45% (n=1401) of the smallholders across the districts sell their crops through vendors or middlemen. Less than 1.5% (n=44) of smallholders use The National Association of Smallholder Farmers of Malawi (NASFAM) as the avenue and market to sell their crops. It highlighted the importance of linking smallholders with profitable markers.

4.2 Socio-Economic Characteristics

4.2.1 Sources of Livelihood

Farmers were asked to mention their 1st, 2nd and 3rd most important source of livelihood.

a. First Source of Livelihood

The participants were asked about the backbone of their socio-economic activities and where they get their primary source of livelihood, and 1570 research participants responded. The questionnaire survey results revealed that smallholder agricultural societies/communities pegged agriculture as more critical in ensuring better income and food security. Crop production and crop sale were the primary livelihood sources for many of the households.

Table 5. Number of smallholders with a preference for "Crop production/sale" as 1st most important source of their livelihoods in 5 districts in Malawi

1st Source of Livelihood	Dowa	Kasungu	Mchinji	Mzimba North	Mzimba South	Rumphi	Total
Crop production/Crop sale	304	344	315	304	230	73	1570
Total	304	344	315	304	230	73	1570

Table 5 above shows that crop production and crop sale is the primary livelihood source in all the districts. All the participants in this study rely on agriculture and selling agricultural products as the source of their livelihood. More than 300 people in each of Dowa, Kasungu, Mchinji, and Mzimba North rely on crop production and crop sale for their livelihoods. Crops such as maize, groundnuts, and soybeans, among others, are the most grown by the smallholder farmers in the study districts.

b. Second Source of Livelihood

Table 6. Number of smallholders with a preference for the various sources of livelihood as 2nd most important source of their livelihood in 5 districts in Malawi

		District						
		Dowa	**Kasungu**	**Mchinji**	**Mzimba North**	**Mzimba South**	**Rumphi**	**Total**
Second most important livelihood source	Crop production/ Sale	3	0	1	25	1	3	33
	Land rental	0	2	2	1	2	0	7
	Gifts	3	1	1	9	12	2	28
	Pension	0	0	0	0	0	1	1
	Artisanal skills	0	0	3	7	0	0	10
	Public works	0	0	0	2	0	0	2
	Entrepreneurship	64	27	19	10	2	12	134
	Petty trade	0	5	4	11	10	2	32
	Fish production and sale	0	0	0	0	2	0	2
	Livestock production/Sale	96	78	70	91	62	26	423
	Natural resources sales	0	3	0	3	0	1	7
	Formal Employment	2	1	1	1	0	0	5
	Casual labour (ganyu)	97	148	129	54	69	11	508
	Semi-skilled work	5	6	2	6	8	1	28
	Begging	0	0	0	0	2	0	2
	Social Cash Transfer	1	3	2	3	0	0	9
	Petty trading/	12	26	30	37	26	9	140

Table 6 above gives an overview of the socio-economic activities which acts as the financial and livelihood cushions for the smallholder farmers in 6 districts. The study documented that in most households, one in 3 people relies on Ganyu or casual labour as the second most important source of livelihood, with Kasungu having the most people compared to other districts. Livestock production and sale also has a significant number of people relying on it (26.9%) for survival and as a second livelihood source, albeit lower than casual labour. However, about 2% still consider agriculture their primary source of livelihood, while almost 12% do not have a second source of livelihood in all the districts.

c. Third Source of Livelihood

Table 7. Number of smallholders with a preference for the various sources of livelihood as 3rd most important source of their livelihood in 5 districts in Malawi

		District						
		Dowa	**Kasungu**	**Mchinji**	**Mzimba North**	**Mzimba South**	**Rumphi**	**Total**
Third most important livelihood source	Crop production/Sale	2	0	0	24	0	3	29
	Land rental	3	6	5	3	2	0	19
	Gifts/Remittances	13	0	2	16	2	5	38
	Pension	0	0	0	0	0	1	1
	Artisanal skills	1	1	0	2	2	0	6
	Fishing	0	0	0	0	0	1	1
	Entrepreneurship	34	3	4	6	0	5	52
	Petty trade	0	6	1	8	3	3	21
	Livestock production/Sale	43	14	12	30	10	6	115
	Natural resources sales	2	1	1	2	0	1	7
	Formal Employment	1	1	1	1	2	0	6
	Casual labour (ganyu)	80	63	46	41	29	10	269
	Semi-skilled work	2	5	2	3	2	1	15
	Social Cash Transfer	2	1	0	2	0	1	6
	Petty trading/business	19	20	11	18	10	10	88

This study documented that many of the households, more than a third of the research participants in all the districts studied, reported not having a third source of livelihood (Table 7). Kasungu has the most respondents without a third livelihood source. Crop production and sale is the third primary source for other participants, while 17% of the respondents rely on casual labour/ganyu. There is a triple-fold increase in gifts and remittances for the respondents from the first source to the third source of livelihood for the farmers.

Table 8. Quantity (kg) harvested, quantity sold, unit price and the total value of various smallholder farm commodities presented with mean values. MWK is Malawian Kwacha. 1 MWK = 0.00098, 1 USD = 1023 MWK.

		Mean		Std. Deviation
		Statistic	Std. Error	Statistic
Groundnut	Quantity harvested in Kg	735	304	8553
	Sold in Kg	262	18	497
	Unit Price	1808	147	4029
	Total value	155272	31170	801988
Soybean	Quantity harvested in Kg	287	50	1665
	Sold in Kg	194	13	440
	Unit Price	1824	134	4299
	Total value	75204	8393	265826
Beans	Quantity harvested in Kg	197	118	1534
	Sold in Kg	44	6	78
	Unit Price	2538	607	7852
	Total value	130607	75377	804816
Maize	Quantity harvested in Kg	1383	66	2188
	Sold in Kg	278	19	648
	Unit Price	625	47	1554
	Total value	83981	14502	388604
Irish potato	Quantity harvested in Kg	384	66	608
	Sold in Kg	317	60	551
	Unit Price	1811	323	2946
	Total value	89281	28747	243927
Sweet potato	Quantity harvested in Kg	1163	601	9306
	Sold in Kg	743	505	7817
	Unit Price	639	106	1641
	Total value	1663874	1579205	-
Vegetables	Quantity harvested in Kg	468	74	998
	Sold in Kg	444	70	923
	Unit Price	2034	1172	15379
	Total value	220000	33781	42840

Table 8 above shows the mean statistical value of yields harvested and sold, the unit price, and the total value earned by smallholder farmers in the Dowa district. Mazie and sweet potatoes had more than 1000 mean average kilograms of harvest with an std. error of 66 and 601 (SD= 2188 and 9306), respectively. As shown by the SD, the farmers' mean statistical values were spread out far away. On the contrary, beans (197kg) and soybeans (287kg) had the lowest average harvests and a respective std. error (118 and 50). The highest average statistic on the kilograms sold by smallholder farmers was on sweet potatoes (743kg, SD=7817), followed by vegetables (444kg, SD=923) and Irish potatoes (317kg, SD=551). On the other hand, beans (44kg, SD=78) and soybeans (194kg, SD=440) had the lowest mean yield sold by the farmers in this study. Furthermore, beans and vegetables have the highest mean unit price among the other studied crops. Beans crops have an SD=7852, while vegetables scored SD=15379. However, the least mean estimated unit price was pegged at 625MK for maize and 639MK for sweet potatoes.

4.4 Conversation Agriculture's impact on smallholder Crop yields and Income

4.4.1 Overview

This section looks at the technologies associated with CA, practised by rural farmers in the Dowa district in Central Malawi. I have looked at the adopted CA technologies of soil water conservation, such as mulching and zero tillage. The study also covers the impact of intercropping, monocropping, and mixed cropping systems on the field harvests of smallholder farmers. The effects of CA technologies practised by smallholder farmers on harvests income were also covered in this section.

4.4.2 Impact of CA on Crops, Yields Income

Table 9. The comparison of *total mean income* (in MWK) for various smallholder farm commodities with respect to their involvement in Conservation Agriculture (CA) practices. MWK is Malawian Kwacha. 1 MWK = 0.00098, 1 USD = 1023 MWK

CA Technology practised	**Groundnuts**	**Soybeans**	**Beans**	**Maize**	**Irish Potato**	**Sweet Potato**	**Vegetables**
No Mulching	84,403	41,934	21,580	35,433	119,285	256,285	308,270
With Mulching	72,444	64,988	51,539	53,217	232,750	98,382	177,808
No Zero Tillage	71,665	59,453	52,728	49,538	125,678	171,156	217,869
With Zero Tillage	90,089	56,015	27,722	47,650	373,700	54,653	188,050
No Mixed Cropping	51,659	145,245	160,333	72,064	141,250	10,000	93,152
With Mixed Cropping	78,121	49,744	36,626	44,877	196,794	132,488	219,658
With Mono-Cropping	63,547	134,170	102,100	74,451	141,250	10,000	100,031
With Inter-cropping	86,091	51,059	44,181	40,731	240,000	152,524	276,000
With Inter, Mixed Crop, Mulch and zero Tillage	122,467	60,036	30,041	36,062	593,333	51,611	231,857
No mulching and No zero tillage	82,179	40,343	21,712	33,682	134,833	349,800	335,225

Table 9 above shows the revenue obtained from selling crops grown under different CA conditions and practices by smallholder farmers. The most revenue returned from the crops grown without the mulching technique was realised on vegetables which is six times over the proceeds from soybeans which had the lowest income under the mulching technique (Table 9). The Irish potato earned the farmers the highest returns (232 750 MK) under mulching, while beans had the lowest total income. Albeit the income from beans under mulch is the least amongst all the crops grown under that technology, the income still doubles that from beans without applying the mulching technique. Those who did not practice zero tillage got the highest income from vegetables, higher than those who employed the same method on the same crop. However, comparatively, the Irish potato brought higher income when put under zero tillage than other crops. The sweet potato crop's revenue recorded less than 1% of beans and the Irish potato when grown under monocropping and without mixed cropping systems.

Table 10. The comparison of total mean income (in MWK) from livestock with respect to their involvement in Conservation Agriculture (CA) practices. MWK is Malawian Kwacha. 1 MWK = 0.00098, 1 USD = 1023 MWK

CA Technology practiced	Cattle	Goats	Chicken	Pig	Milk	Meat	Eggs
Mulching -NO	960,000	20,062	15,404	71,857	288,000	32,000	2,533
Mulching -Yes	430,000	70,370	32,734	69,771	45,000	16,000	6,1450
Zero Tillage -NO	580,000	60,545	13,193	64,000	166,500	16,000	2,028
Zero Tillage -Yes	660,000	72,500	78,934	81,133	--	32,000	121,250
Mixed Cropping -No	--	52,333	7,916	64,000	--	--	2,000
Mixed Cropping -Yes	606,666	64,711	30,345	71,342	166,500	24,000	49,720
Mono-Crop -Yes	--	51,000	11,222	96,888	--	--	2,000
Inter Crop -Yes	606,666	72,096	16,540	89,550	166,500	32,000	121,775

Inter, Mixed Crop, Mulch and zero Tillage YES	660,000	74,166	16,615	111,125	--	--	480,000
No mulching and No zero Tillage	960,000	20,062	15,921	74,600	288,000	--	2,533

Table 10 above illustrates the total income from smallholder farmers' different livestock products.

Farmers were asked if they were doing any of the CA technologies mentioned in the table. More revenue was obtained from cattle and pigs where mulching was not implemented compared to farms that practiced mulching (table 10). However, goats and chickens brought double the income for the mulching-practicing farmers than those with no mulching. In general, cattle income is similar for most farmers practising CA technologies except non-mulching and those that did not use a combination of no mulching and zero tillage, which are outstanding. Additionally, the income from cattle, goats, pigs, and chicken is higher for zero-tillage farmers compared to those who did not use zero-tillage farming practices. Also, mixed cropping farmers realised more income from cattle, goats, chickens and pigs than those who did not practice mixed cropping technique, with chicken income being the most outstanding (4 times higher than the income of mixed cropping farmers).

Table 11. Comparison of *mean quantity sold* (in kg) for various smallholder farm commodities with respect to their involvement in Conservation Agriculture (CA) practices. MWK is Malawian Kwacha. 1 MWK = 0.00098, 1 USD = 1023 MWK

CA Technology practiced	Groundnuts sold kg	Soybeans sold kg	Beans sold kg	Maize sold kg	Irish Potato sold kg	Sweet Potatoes sold in kg	Vegetables sold kg
Mulching-NO	97	135	23	187	468	104	721
Mulching-YES	57	157	44	345	783	307	598
Zero tillage-NO	68	145	46	299	470	243	629
Zero tillage-YES	60	174	22	321	1220	304	619
Mixed cropping-NO	38	109	124	542	400	50	442
Mixed cropping-Yes	70	156	33	267	686	272	641
Mono cropping-Yes	54	115	142	528	400	50	441
Intercropping-Yes	68	159	35	232	788	205	804
Inter, mixed crop mulching, zero Tillage-YES	63	168	24	194	1883	210	558
No mulching and No-zero Tillage	98	127	25	173	507	87	596

Table 11 above represents the quantity sold from the harvested crops by smallholder farmers who practiced different CA technologies in their fields. More vegetables were sold from non-mulch practicing farms compared to other crops in the study. The average quantity sold by farmers who practiced zero tillage technique was more on Irish potatoes and less on beans, which averaged 22.4kg. Comparatively, those who did not practice zero tillage sold the highest mean produce of 629.1kg, with beans having the lowest average quantity of 46.6kg. Irish potato had the highest mean total amount sold by farmers who practiced mulching, zero tillage, mixed cropping, intercropping (similar to vegetables), those who practiced

[Inter, mixed cropping, mulching, zero tillage] in their fields. Also, the Irish potato average total quantity sold was higher, similar to the average amount of vegetables.

Table 12. The comparison of total quantity sold (in kg) from livestock with respect to their involvement in Conservation Agriculture (CA) practices. MWK is Malawian Kwacha. 1 MWK = 0.00098, 1 USD = 1023 MWK

Code	**Cattle sold**	**Goats sold**	**Chicken sold**	**pig sold**	**milk Quantity**	**Meat Quantity**	**#Eggs**
Mulching NO	8	1	6	2	960	20	32
Mulching YES	1	2	18	2	150	8	94
Zero tillage NO	4	2	5	2	555	8	25
Zero tillage YES	2	2	48	1	--	20	167
Mixed cropping NO	--	2	3	2	--	--	40
Mixed cropping Yes	3	2	16	2	555	14	81
Mono cropping Yes	--	2	4	2	--	--	40
Intercropping Yes	3	2	6	2	555	20	171
inter and mixed cropping mulching and zero Tillage YES	2	2	6	2	--	--	600
No mulching and No zero Tillage	8	1	6	2	960	--	32

The average total of goats and pigs sold by farmers in all categories is similar and averages two livestock. The number of chickens sold averages a minimum of 3 and the highest of 48.5, while cattle's highest mean sold is 8 (table 12).

Table 13. Comparison of *mean total yield* (in kg) for various smallholder farm commodities with respect to their involvement in Conservation Agriculture (CA) practices. MWK is Malawian Kwacha. 1 MWK = 0.00098, 1 USD = 1023 MWK

CA Technology practiced	Ground nuts harvested	Soybeans harvested	Beans harvested	Maize harvested	Irish Potato harvested	Sweet Potato harvested	Vegetables harvested
Mulching NO	231	170	48	1985	543	276	814
Mulching YES	117	199	388	2074	920	588	664
Zero tillage NO	138	182	407	1994	528	529	692
Zero tillage YES	156	224	56	2299	1494	510	714
Mixed cropping NO	233	125	140	2413	400	110	457
Mixed cropping Yes	131	198	301	1996	810	536	718
Mono cropping Yes	96	137	161	2633	400	110	451
Inter Cropping Yes	134	200	66	2103	957	395	911
Inter, Mixed cropping, Mulch, Zero Tillage YES	178	214	49	2345	2340	378	712
No mulching and No zero Tillage	230	156	51	2035	592	280	697

Table 13 above illustrates the average total yield from the crops and CA-associated practices employed. The total mean maize yield under mulching practice is similar to that of no mulching practice, however, slightly higher (Table 13). Beans' mean output performed well under mulching. However, the Irish potato had poor yields without mulching. Hence the impact of CA technologies differs with crops. The average mean yield of maize was higher than that of all the crops, both with and without CA practices. However, the differences in maize average yield under mulching, zero tillage or cropping systems were not massive for both farmers. Vegetables, soybeans, and Irish potato yields increased under all the CA practices in the study compared to non-practices.

Table 14. Comparison of *the mean total area under cultivation (in hectares)* for various smallholder farm commodities with respect to their involvement in Conservation Agriculture (CA) practices. MWK is Malawian Kwacha. 1 MWK = 0.00098, 1 USD = 1023 MWK

CA Technology practiced	Groundnuts Area planted	Soybean Bean Area planted	Beans Area planted	Maize Area planted	Irish Potato Area planted	Sweet Potato Area planted	Vegetables Area planted
Mulching NO	0.31	0.4	0.3	0.6	0.1	0.1	0.1
Mulching YES	0.4	0.9	0.2	0.6	0.3	0.1	0.45
Zero tillage NO	0.38	0.9	0.2	0.6	0.1	0.1	0.43
Zero tillage YES	0.36	0.4	0.2	0.7	0.4	0.1	0.2
Mixed cropping NO	0.4	0.1	0.4	0.6	0.1	0.1	0.1
Mixed cropping Yes	0.38	0.9	0.2	0.6	0.2	0.1	0.46
Mono cropping Yes	0.4	0.1	0.3	0.6	0.1	0.1	0.1
Intercropping Yes	0.39	0.3	0.2	0.6	0.3	0.1	0.1

inter and mixed cropping, mulching, zero Tillage YES	0.4	0.2	0.2	0.8	0.3	0.1	0.2
No mulching and No zero Tillage	0.3	0.2	0.31	0.6	0.1	0.1	0.1

The average area planted groundnuts under different cropping systems, and soil water conservation techniques is almost 0.3 acres. Maize crops had the highest average land area placed under different CA technologies, mainly because it is the staple crop for the smallholder farmers in Malawi. In contrast, sweet potatoes had the smallest land area (0.1 hectares) allocated to each CA technology practised (Table 14). On the other hand, soybeans were allocated a higher land area (0.9 hectares) under mulching, mixed cropping systems, and conventional farming practices.

Table 15. Comparing the mean harvest (kg) values of smallholders involved in Mono, mixed and inter-cropping for various smallholders produce

Mean Harvests/Yield values (kg)	Mono	Mixed	Inter
Groundnuts harvested	76	131	134
Soyabean harvested	128	198	200
Beans harvested	221	301	66
Maize harvested	2 454	1996	2103
Irish potato harvested	400	810	957

Sweet potato harvested	110	536	395
vegetables harvested	451	718	911

The impact of cropping systems on the mean harvests of groundnuts under mixed and intercropping systems almost doubles that of monocropping yields (Table 15). The average yield total from mixed cropping and intercropping on soybean crops was a third more than that from the monocropping system. In contrast, monocropping impacted the yield of Irish potatoes by 50% less than the other cropping systems. It is imperative to know that vegetables, sweet potatoes, and Irish potatoes have all performed above par under either mixed cropping or intercropping compared to the monocropping system. However, the impact of the cropping system on maize was similar under all the cropping systems, though monocropping was almost 5% slightly higher.

Table 16. Comparing the mean total income (MWK) values of smallholders involved in Mono, mixed and inter-cropping for various smallholders produce

Mean Income values	**Mono-cropping**	**Mixed cropping**	**Intercropping**
Groundnuts Total Value (MWK)	51 138	78 121	86 091
Soyabean Total Value (MWK)	158 800	49 743	51 058
Beans Total Value (MWK)	160 333	36 626	44 181
Maize Total Value (MWK)	82923	44 877	40 731

Irish potato Total Value (MWK)	141 250	196 794	240 000
Sweet potato Total Value (MWK)	10 000	132 488	152 524
Vegetables Total Value (MWK)	100 031	219 658	276 000

Table 16 above represents the average income/value (in Malawian Kwacha) of the harvested crops by the smallholder farmers in the study.

In this study, the mean total income for groundnuts, vegetables, sweet potatoes, and Irish potatoes was recorded from the farms practicing intercropping. At the same time, monocropping has the lowest income for the same crops. Surprisingly, the mean total income for maize crops was under the monocropping system compared to mixed and intercropping systems.

Table 17. ANOVA analysis for the farmers' average total income from Ground nut. Group 1: practicing mulching, zero tillage, crop cover and crop rotation, while Group 2: No mulching, No zero tillage, no crop cover and no crop rotation.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F statistic	p-value
Treatments	73662574	1	73662574	0.010299	0.93
Error	1.57E+11	22	7.15E+09		
Total	1.57E+11	23			
Summary Statistics					
	Group 1		**Group 2**		
Mean	84196.43		87750		
STD Dev	86603.22		81548.97983		
Min	8000		4500		
Median	45000		74250		
Max	270000		260000		
Skewness	1.26		1.145		
Kurtosis	0.618		0.89		
SS Dev	9.75E+10		59852125000		
Observations	14		10		

Table 18. ANOVA analysis for the farmers average total income from Soyabean. Group 1: practicing mulching, zero tillage, crop cover and crop rotation, while Group 2: No mulching, No zero tillage, no crop cover and no crop rotation.

Source of Variation	Sum of Squares	Degrees of freedom	Mean Square	F statistic	p-value
Treatments	1.8E+09	1	1.8E+09	1.407735	0.4
Error	4.74E+10	37	1.28E+09		
Total	4.92E+10	38			
Summary Statistics					
	Group 1		**Group 2**		
Mean	53763.16		40160		
STD Dev	33913.85		37477.36721		
Min	6000		1800		
Median	50000		27500		
Max	120000		125000		
Skewness	0.243864		1.19		
Kurtosis	-0.74516		0.48		
SS Dev	2.07E+10		26686508000		
Observations	19		20		

Table 19. ANOVA analysis for the farmers average total income from Maize. Group 1: practicing mulching, zero tillage, crop cover and crop rotation, while Group 2: No mulching, No zero tillage, no crop cover and no crop rotation.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F statistic	p-value
Treatments	1.54E+08	1	1.54E+08	0.350365	0.659755799
Error	1.1E+10	25	4.4E+08		
Total	1.11E+10	26			
Summary Statistics					
	Group 1	Group 2			
Mean	31923.08	27142.85714			
STD Dev	20031.07	21795.75521			
Min	7000	6000			
Median	30000	16000			
Max	70000	72000			
Skewness	0.521556	0.867233657			
Kurtosis	-0.62932	-0.641048008			
SS Dev	4.81E+09	6175714286			
Observations	13	14			

Table 20. ANOVA analysis for the farmers average total income from Sweet potato. Group 1: practicing mulching, zero tillage, crop cover and crop rotation, while Group 2: No mulching, No zero tillage, no crop cover and no crop rotation.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F statistic	p-value
Treatments	2.36E+11	1	2.36E+11	1.077738	0.488087725
Error	1.97E+12	9	2.19E+11		
Total	2.21E+12	10			
Summary Statistics					
	Group 1	Group 2			
Mean	55583.33	349800			
STD Dev	49394.75	699871.5596			
Min	24000	9000			
Median	32250	30000			
Max	150000	1600000			
Skewness	1.88017	2.220551237			
Kurtosis	3.410815	4.942357578			
SS Dev	1.22E+10	1.95928E+12			
Observations	6	5			

Table 21. ANOVA analysis for the farmers average total income from vegetables. Group 1: practicing mulching, zero tillage, crop cover and crop rotation, while Group 2: No mulching, No zero tillage, no crop cover and no crop rotation.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F statistic	p-value
Treatments	1.95E+10	1	1.95E+10	0.212012	0.72529321
Error	3.13E+12	34	9.22E+10		
Total	3.15E+12	35			
Summary Statistics					
	Group 1	Group 2			
Mean	205300	157500			
STD Dev	284834.7	314732.3504			
Min	200	2000			
Median	67000	64000			
Max	800000	1500000			
Skewness	1.378505	4.033590034			
Kurtosis	0.459059	17.54665426			
SS Dev	1.05E+12	2.08019E+12			
Observations	14	22			

Smallholders involved in practicing mulching, zero tillage, crop cover and crop rotation, were earning similar income compared to these smallholders who were not practicing CA practices (Table 17-21).

Chapter 5. Discussion

5.1 Overview

This chapter covers the discussion of the study results. The study objectives were to 1) investigate the impact of technologies associated with CA on smallholder farmers' yields and 2) the impact of crop yields on the income of smallholder farmers who practices these technologies, focusing on the Dowa district. Firstly, I have looked at the irrigation types used by smallholder farmers, the CA-associated components (mulching, zero tillage, cropping systems) practiced by the smallholder farmers in the Dowa district, and their impact on improving yields of specific crops such as maize, groundnuts, Irish potato, sweet potatoes, vegetables, soybeans, and beans. Secondly, the chapter looked at the impact of CA on smallholder farmers' income from agricultural produce. The chapter lastly discussed the role of livestock in improving the smallholders' revenue.

5.2 Irrigation methods by smallholder farmers in Dowa district

The bucket system is the most widespread form of irrigation employed by the farmers in the Dowa district. In Chiwamba (Lilongwe rural) and Bwengu EPA (Mzimba North) in Malawi, Andersen (2019) investigated the impact of the Leader farmer extension approach and how crop yields responded to the CA technologies under the programme. In the study, follower farmers (FFs) requested training on new irrigation technologies, such as treadle pumps, as most smallholders use buckets for irrigation for farming.

5.3 Sources of livelihood of smallholder farmers in Dowa district

The study shows that Malawi is an agricultural society, as crop production and sale constitute the highest form of livelihood for smallholder farmers. However, casual labour/ ganyu was an off-farm economic activity that was the second most important to the farmers. Ganyu is done by women, children, and men, for their relatives, neighbours, and to other farmers – smallholders or estates. Primary actives of ganyu entail ridging (land preparation done before the next planting season) and weeding – which is done during the Planting and growing season noted Bouwman et al. (2021). Ganyu is mainly done during the season when farmers' stocks are depleted while crop harvests are months away. *Casual labour* is a piecework job done in the space of day/s or weeks (paid per weeded area, in cash or kind). Ganyu/casual labour posits numerous vital features, such as production ganyu constitutes an essential livelihood strategy of rural households after own-farm (Carr et al., 2017; Whiteside., 2000).

5.4 Impact of Conversation Agriculture technologies on crop yields

5.4.1 Mulching and Zero tillage on crop yields

The study was conducted to see how mulching and zero tillage effects crop yields of groundnuts, maize, sweet potato, beans, soybeans, Irish potato, and vegetables. The study was conducted to see how mulching and zero tillage effects crop yields of groundnuts, maize, sweet potato, beans, soybeans, Irish potato, and vegetables. The results of this study reveal that mulching is vital to improving crop yields. Maize yield performed higher than any crop in this study when grown with and without mulching. It is also imperative to note that maize had higher mean total yields under mulching technology compared to zero mulching practices. This result corroborates with other studies by Bouwman (2017), who reported a substantial increase in crop yields under ex situ NT conditions (no-till with imported crop residues/mulching) by 87% in the first year of transitioning from ridge furrow cultivation (RFC), and by 108% in other years. Another study by Bana and Prijono (2013) stated that the soil water conservation components, such as tillage and mulching, significantly positively impacted maize crop yield. In this study, maize has showcased a stable crop grown in both mulching and no mulching conditions, as the differences were modest or minimal (Table 13). Other crops -sweet potato, Irish potato, beans, and soybeans- including maize, have all increased their yields under mulching. Mulching promotes percolation and aides the soil water/moisture retention capacity. In addition, mulching reduces evapotranspiration in arid and semi-arid climates (Rusinamhodzi., 2016).

On the other hand, bean harvests were meagre without mulching practice compared to other crops, while groundnut yields plummeted by almost 50% under mulching, more than any other crop. One reason that could explain the modest yields of the groundnut crop is the lack of use of herbicides for weeds that 'consumes' the crops when mulch and zero tillage are applied on the field. Bouwman et al. (2020) found in their study in Nkhotakota and Salima districts that households who adopted herbicide technologies tended to become food secure over time. In their study, households relying on ganyu/casual labour without access to herbicides experienced low yields. They were food insecure and remained poor compared to those that afford herbicide costs, who continued to be better off and food secure. In addition, mulching is also detrimental to crop yields – groundnuts- in areas with clay soils where infiltration is widely reduced and in high rainfall areas.

Zero tillage was tested on several crops to determine its effect on crop yields. This study recorded more groundnuts, soybeans, maize, Irish potato, and vegetables under zero tillage compared to crop yields in conventionally tilled farms (Table 13). In Chiwamba (Lilongwe rural) and Bwengu EPA (Mzimba North) in Malawi, Andersen (2019) investigated farmers have recorded a tremendous increase in crop yields and food security due to the practice of mulching, zero tillage, and crop interactions. Nevertheless, it must be underlined that no enormous difference in yields between zero tillage practice and non-practice was recorded in this study. Bouwman (2019) reported in her study conducted in Malawi's districts of Zidyana and Mwasambo where most 'In situ NT' -zero tillage without mulching- plots had no ground cover, and the impact on crop yields was neither substantial nor negligible (with a rough estimate increase of 11-17%). Hence, the minimal difference between the adopters and non-adopters of CA technologies is projected in this study.

Conversely, the yields of beans fell drastically under zero tillage compared to conventional tillage. In contrast, a slight decrease in sweet potatoes' crop yield was reported under conventional tillage methods than zero tillage. Ngwira et al. (2014a), in Central Malawi, found that no-till without mulching significantly reduced crop yields by about 20 per cent compared to RFC, mainly when fertilizer was applied (yields were similar when fertilizer was not applied). Another study that concurs with the study's result was conducted by Bouwman (2017) in Malawi, which reports and concludes that 'no-tillage without residues depressed yield by 50% when compared with yields of conventional tillage.' Yields tend to suffer when no-tillage is used without crop residue and ground cover. In addition, Erenstein et al. (2012) argue that the application of minimal soil disturbance without practicing crop residue cover, 'under some circumstances, can be more harmful to agroecosystem productivity and resource quality than a continuation of conventional practices.' Other studies in Southern Africa, as reported by Rusinamhodzi et al. (2011) in Zimbabwe, agree with this study's results that SWC methods such as no-till and mulch registered no effect on crop yield compared to conventional tillage practices.

5.4.2 Cropping System on crop yields

Crop yields have responded differently to the study's practiced cropping systems by smallholder farmers. Therefore, the study focused on three cropping systems: mixed cropping, intercropping, and monocropping and their impact on improving crop yields of groundnuts, maize, sweet potato, Irish potato, beans, soybeans, and vegetables.

Maize yields grown under a mixed cropping system were more than those in other cropping systems. Generally, mixed cropping has improved the yields of soybeans, beans, Irish potato, sweet potato, and vegetables compared to harvests from fields without mixed cropping. This study's results concur with Andersen's (2019) findings in rural Lilongwe and Mzimba North in Malawi that crop diversification has led to improved yields and family nutrition. However, the difference in crop yields between maize crops under mixed cropping and other cropping systems was insignificant. In addition, the Laikipia CA programme results on maize yields in Kenya were virtually the same for managed CT and CA plots (Kaumbutho & Kienzle., 2007). On the other hand, groundnut yields were more without mixed cropping compared to mixed cropping practices. Similarly, maize harvests were more under non-mixed cropping conditions than mixed cropping practices; however, the difference was not huge.

which reported that crop yields under crop interactions and rotations positively impact no-tillage practices, concurring with Karlen et al. (1991). In their study, they documented that intercropping and crop rotations have the potential to usher greater yields across soil fertility areas (Karlen & Doran., 1991). A study in Mozambique by Mango et al. (2017) reported that CA has improved and substantiated the yields. In addition, it improved the Food Consumption Score of farmers due to the simultaneous promotion of CA and other better cropping management practices, such as timely weeding and improved varieties (Mango et al., 2017).

More so, the study shows the more positive impact of both mixed and intercropping on crop harvests than monocropping. Overall, it is fundamental to note that the difference between monocropping and mixed or intercropping on maize crops was insignificant. The research findings are similar to the experimental data by Mupangwa et al., 2012; Ngwira et al., 2013; Thierfelder et al., 2015; Mupangwa et al., 2017, which exhibit a positive impact of conservation agriculture technologies on crop yield and agricultural produce (Kiboi et al., 2017). Andersen

(2019) reported that in Mzimba North and Lilongwe rural, smallholders who practiced these CA technologies following the 2018 drought, which impinged on agriculture, harvested more food crops than those who did not embrace the technology. More so, in the same report, Andersen (2019) posits that lead farmers and follower farmers were both able to harvest more yields from small fields as the crops survived dry spells.

However, in central Malawi's EPAs of Tembwe, Zidyana, and Mwansambo, where CA has been promoted and practiced for the longest while, Bouwman et al. (2020) found that farmers are adapting, not adopting. Hence, in their study, the authors reported that the practice of intercropping or crop rotation was substantially reduced following farmers' reduction of mulch retained in their fields. The Monocropping system saw an increase in maize yield in this study, compared to the mixed cropping system. Maize is the most grown crop by smallholder farmers and low yields, and livestock grazing had left the ground literally bare, thus discouraging mulching and intercropping (ibid.). Similar to this study's results, (Bouwman., 2020) and (Mango et al., 2017) have reported no significant impact of conservation adoption on farm productivity and Food consumption Score of farmers in Malawi and Zimbabwe.

5.5 Impact of CA produce on smallholder farmers' income

The study examined how farming involving CA technologies impacts smallholders' income compared to non-CA farms in the Dowa district. Vegetables had the highest mean income generated from crops grown without mulching. Crops, such as soybeans, beans, maize, and Irish potato, have generated a substantially higher mean income than those using crop residue or mulching practices, although the difference was not significant. These results are substantiated by Andersen's investigation in the Mzimba North district of Malawi, which found that smallholder farmers got bumper yields and received good revenue from selling surplus products (Andersen., 2019). In the study, the author mentioned that even the youth became self-reliant and independent from their parents as they could sell surplus food/produce.

On the contrary, the study reveals that those who planted vegetables, sweet potatoes, and groundnuts with mulch obtained less revenue than those who did not. Similarly, those who did not use zero tillage on groundnuts and Irish potatoes received less revenue from their crops than those who did. Agricultural products and revenue are contingent on the quantity sold and, to some extent, depend on the quantity harvested by the farmer. In a nutshell, the difference in income for those who practiced the CA-associated technologies and those who did not, was not statistically significant. Thus, calling for more studies to substantiate the findings in the study area.

Furthermore, it is essential to note that this study shows that most smallholder farmers sell their crops through vendors or middlemen. However, this could have an impact on the profits of farmers as there is no direct connection between their produce and the market; it has ensured access to markets for farmers. This result is contrary to the findings in Chiwamba and Bwengu, where farmers no longer sell their crops through vendors/middlemen, which would shrink their profits. Instead, they are operating in groups and access the markets without middlemen, a move which has enhanced their profits which are in turn used for sending children to school, buying iron sheets for roofing, and/or investing in the village savings and loans groups (Andersen., 2019).

5.6 Impact of livestock on smallholder farmers' income

Smallholder farmers in this study have received the highest mean income from selling cattle compared to goats, chickens, and pigs. Cattle have the highest mean income for smallholder farmers in the Dowa district in Malawi. According to Randolph et al. (2007), for smallholders, livestock provides an effective nutritional supplement to vulnerable groups and boosts many households' resilience during food crisis periods. Households that did not practise mulching had the highest mean income from cattle. A study by Banda et al. (2011) in Lilongwe, Kasungu, Thyolo, and Mzimba districts, on livestock and dairy farming in Malawi, is reported to have generated more income. Similarly, those who did not practice mulching and zero tillage on their farms have the same revenue level as those that did not embrace mulching. Chicken generated the most negligible revenue for the smallholders.

Chapter 6

6.0 Conclusion and recommendations

6.1 Overview

The chapter summarizes the study results, conclusions made from the study, and possible recommendations for future work and studies. The sections in this chapter follow the sequence of the research study's objectives. The chapter also highlights areas that require further research.

6.2 Conclusions

The study examined the effect of conservation agricultural features on the harvests of several crops, including corn, beans, soybeans, groundnuts, vegetables, Irish potato, and sweet potato. The study examined CA practices such as mulching, zero tillage, and cropping systems on crop yields using SPSS analysis software. ANOVA test was used to determine the effect of mulching, no-tillage, and cropping systems on the income of smallholder farmers from crop production or sale. The study has shown evidence that most yields of the crops in this study thrive and perform well under mulching and zero tillage. Many households have adopted mulching and cover-plant to improve soil moisture content. However, the research shows that there is only a slight distinction between the crop yields of farmers who used CA-associated technology and those who did not. Higher earnings from the selling of agricultural products and crops were documented alongside increased yields. Most households in the Dowa district in Malawi practice rainfed irrigation on their farms. The study also found that most respondents use buckets for irrigation purposes. The study results also demonstrated that Malawi is a maize staple nation, as maize is the most grown crop. Also, maize had the highest yields under soil water conservation methods practiced by smallholders. In addition, the maize crop's yield increased under mulching and zero tillage. The CA practices, for some crops, have improved yields but there is no significant difference between the conventional crop output and CA practices from the same crops.

6.3 Recommendations

- ❖ Overall, the impact of CA practices on smallholder-based production systems was minimal, emphasizing the significance of tailored-made practices that encompass the "Whole farm approach" idea.
- ❖ Training smallholders to diversify their revenue streams can help them mitigate the risks associated with relying on any one of them too heavily. It is possible to build resilience in food and livelihood systems by adopting the “Whole farm approach”.
- ❖ The majority of smallholders need to be able to afford and easily implement CA practices and other technologies. For instance, even though many organizations help smallholder farmers by providing irrigation supplies like treadle pumps, very few people utilize them because most smallholders instead use non-renewable methods like buckets.
- ❖ More opportunities for small farmers to sell their goods directly to consumers (rather than through an intermediary) in well-paying markets.

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