

An economic analysis of smallholders' heterogeneity and the impact of *Jatropha curcas* cultivation on household welfare in the Mangochi District, Malawi

By:

Owen Yoram Chamdimba

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School of Agricultural, Earth and Environmental Sciences

College of Agriculture, Engineering and Science

University of KwaZulu-Natal

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ABSTRACT

The renewed interest in biofuels among many countries globally is on account of potential increased energy security, environmental and rural development benefits. Biofuels development in Malawi has the potential to achieve these objectives. The agricultural sector is the engine of the economy. Tobacco, the current primary foreign exchange earner, faces dwindling revenues from anti-smoking campaigns. Smallholders are also affected by various shocks, including weather variation, which increase vulnerability to food insecurity. There is no doubt that Malawi needs to diversify its economy to mitigate shocks and improve rural livelihoods.

The Malawi government recognises, among other strategies, increased use of renewable energy sources, increased agricultural productivity, and diversification as its key priority areas. The smallholder out-grower biofuels production schemes deliver on two key government priority areas as renewable energy sources and crop diversification with the potential to open new markets, create rural jobs, and improve livelihoods. Generally, research on energy crops in Malawi is thin. The nexus of livelihood, food security, and biofuels production has not been examined in Malawi. Thus, this study aims to: (1) identify sources of smallholder heterogeneity and farmer typologies among energy crop producers, to inform livelihood improvement interventions in Southern Malawi; (2) analyse the determinants and the impact of *Jatropha curcas* cultivation on resilience to food insecurity shocks among smallholders, and (3) examine the welfare impacts of *Jatropha curcas* cultivation on smallholders in Southern Malawi. The study used cross-section data collected in 2014 using purposive and random sampling strategies from 298 smallholders in the Mangochi District of Southern Malawi. Mangochi District was chosen following reconnaissance survey results where Bioenergy Resources Limited (BERL), a consortium of Dutch Companies engaged in biofuels promotion in Malawi, was getting the bulk of *Jatropha curcas* seeds. The empirical research techniques employed include Principal Component Analysis (PCA), Cluster Analysis (CA), Endogenous Switching Regression model (ESR), Propensity Score Matching (PSM), and the Endogenous Treatment Effects (ETE) model.

The multivariate analysis results identified five typologies that were generally distinguished by gender, asset holdings, labour endowments, level of agricultural input use, and output sales. The typologies exhibited various constraints and opportunities for livelihood improvement. Notably, more *Jatropha curcas* cultivating farmers, particularly female-headed households, belonged to typologies with low to medium resource endowments as compared to non-growers. There were variations in possible interventions across many of the typologies identified. Hence,

interventions and strategies must target the identified typologies, where capacity is available to increase their impact and relevance. The portfolio of interventions identified range from human capital (extension), labour-intensive strategies such as work for inputs to social protection measures (safety-nets).

The endogenous treatment effects model results showed that shocks, various capital assets, and institutional factors were significant determinants of resilience to food insecurity. *Jatropha curcas* cultivating farmers, particularly female-headed households, had significantly less resilience capacity to food insecurity compared to their counterparts. These results imply that policies and strategies that promote increased access to services and build people's capacity (such as institutional support to credit, quality education) should be given priority to increasing resilience to food insecurity.

The findings of the propensity score matching and endogenous switching regression methods suggest that, when selection bias and endogeneity were accounted for, there were welfare benefits to smallholder *Jatropha curcas* feedstock producers. As such, there is a need for more empirical research on other potential biofuels to inform the Malawi biofuels policy in the future.

In sum, the study has shown that biofuels are not a panacea that reduces rural poverty and improves the welfare of smallholders. Thus, future research must focus on developing and disseminating a portfolio of more profitable technology/practice packages for *Jatropha curcas* to contribute to rural household welfare. Furthermore, the study recommends policy efforts aimed at increasing resilience to food insecurity shocks. This could be achieved by increased access to credit, quality education, and strengthening climate forecasting capacity through research in climate models. Promotion of climate-smart agriculture practices is also recommended to reduce the impact of weather shocks. Where capacity is available, tailor-made interventions for livelihood improvement such as income or crop diversification, public works for inputs, and safety nets need to target specific groups based on smallholders' unique characteristics to account for heterogeneity.

PREFACE

The research contained in this thesis was completed by the candidate while based in the Discipline of Agricultural Economics, School of Agricultural, Earth and Environmental Sciences of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg Campus, South Africa. The research was financially supported by the candidate privately.

The contents of this work have not been submitted in any form to another university, and, except where the work of others is acknowledged in the text, the results reported are due to investigations by the candidate.



Signed: Professor G.F. Ortman

Date: 27 July 2021 _____



Signed: Professor E.W. Zegeye

Date: __ 27-07-2021 _____

DECLARATION 1: PLAGIARISM

I, *Owen Yoram Chamdimba*, declare that:

- i. The research reported in this thesis, except where otherwise indicated or acknowledged, is my original work;
- ii. this thesis has not been submitted in full or in part for any degree or examination to any other university;
- iii. This thesis does not contain other persons' data, pictures, graphs, or other information unless specifically acknowledged as being sourced from other persons;
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 - a. their words have been re-written, but the general information attributed to them has been referenced;
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- v. where I have used material for which publications followed, I have indicated in detail my role in the work;
- vi. This thesis is primarily a collection of material, prepared by myself, published as journal articles or presented as a poster and oral presentations at conferences. In some cases, additional material has been included;
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We hereby agree to the submission of this thesis for examination:

Signed:  Date: 27 July 2021
Professor G.F. Ortman

Signed:  Date: 27-07-2021
Professor E.W. Zegeye

DECLARATION 2: PUBLICATIONS

The following publications (submitted and published) form part of the research outputs presented in this thesis.

Publication 1 – Chapter 3 of this thesis

Chamdimba, O.Y., Ortmann, G.F. & Wale, E. A rural household typology, characterisation of smallholders, and *Jatropha curcas* feedstock producers in southern Malawi: constraints and opportunities for improving livelihoods. Submitted to *Land Use Policy*, under review.

Publication 2 – Chapter 4 of this thesis

Chamdimba, O.Y., Ortmann, G.F. & Wale, E. 2020. Resilience to shocks and food insecurity: determinants, and the impact of smallholder *Jatropha curcas* cultivation in southern Malawi. *African Journal of Science, Technology, Innovation and Development*:1-15.

Publication 3 – Chapter 5 of this thesis

Chamdimba, O.Y., Ortmann, G.F. & Wale, E. 2019. Biofuels and livelihoods: empirical findings on the welfare impacts of *Jatropha curcas* cultivation in southern Malawi. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 120 (2):129-140.

Conference papers

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presented at the 54th Annual Conference of the Agricultural Economics Association of South Africa (AEASA), 14th-16th September 2016, Durban, South Africa.

The data used in the above publications were collected, analysed, and discussed in the empirical articles listed above by Owen Yoram Chamdimba, with technical expertise from Prof G.F. Ortmann and Prof E. Wale. All the figures, graphs, and tables were produced by the same author unless otherwise referenced in their respective publication.

DEDICATION

This thesis is dedicated to my family and in loving memory to my late parents.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADD	Agriculture development division
AEU	Adult equivalent units
AGRA	Alliance for a green revolution in Africa
AIP	Affordable Inputs Program
ANOVA	Analysis of variance
ATE	Average Treatment Effect
ATET	Average Treatment Effect on the Treated
BERL	Bioenergy Resources Limited
CA	Cluster Analysis
CIA	Conditional independence assumption
CGE	Computable General Equilibrium
CPO	Crude Palm Oil
CRS	Congressional Research Service
FGDs	Focus Group Discussions
FGT	Foster Greer Thorbecke
EIA	Energy Information Administration
ESR	Endogenous Switching Regression
ETE	Endogenous Treatment Effects
ETHCO	Ethanol Company
EPA	Environmental Protection Agency
EPAs	Extension Planning Areas
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations

FAOSTAT	Food and Agricultural Organization Statistics
FIML	Full Information Maximum Likelihood
FISP	Farm Input Subsidy Program
GDP	Gross Domestic Product
GHG	Green House Gases
GREET	Greenhouse gases, Regulated Emissions and Energy use in Transport
IAP	Indoor Air Pollution
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
JCFs	<i>Jatropha</i> Cultivating Farmers
ICEIDA	Icelandic International Development Agency
IFPRI	International Food Policy Research Institute
ISFM	Integrated Soil Fertility Management
ILUC	Indirect Land-Use Changes
LCA	Life Cycle Assessment
LUC	Land-Use Changes
MERA	Malawi Regulatory Authority
MBS	Malawi Bureau of Standards
MGDS	Malawi Government Growth and Development Strategy
MRFC	Malawi Rural Finance Company
MLE	Maximum likelihood estimates
MBS	Malawi Bureau of Standards
NAIP	National Agricultural Investment Plan
NAP	National Agriculture Policy

NJFs	Non- <i>Jatropha</i> Farmers
NSO	National Statistical Office
NTB	Non-tariff barriers
OECD	Organisation for Economic Co-operation and Development
PCA	Principal Component Analysis
PRA	Participatory Rural Appraisal
ProBEC	Programmes for Biomass Energy Conservation
PSM	Propensity Score Matching
PPP	Public-Private Partnerships
RED II	Renewable Energy Directive II
RFS	Renewable Fuel Standards
RRA	Rapid Rural Appraisal
RIMA	Resilience Index and Measurement Analysis
SEM	Structural Equation Modelling
SSA	Sub-Saharan Africa
SADC	Southern Africa Development Community
RDP	Rural development programme
UNDP	United Nations Development Programme
UNEP	United Nations Energy Programme
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WHO	World Health Organization
WTO	World Trade Organisation

Chapter 1. Introduction

1.1 Background

The renewed interest in biofuels among many countries globally is on account of potential increased energy security, environmental and rural development benefits (HLPE, 2011; HLPE, 2013a). The motivations frequently cited in the literature can be categorised broadly into public interest goods for the state (like energy security, environmental protection, food (in)security, etc.) and private outcomes for stakeholders (such as increased incomes, profit, etc.). The recent emphasis on biofuels in the last two decades has been accelerated by events, like relatively high and volatile crude oil prices and perceived economic and environmental benefits (Rosegrant *et al.*, 2008; Searchinger *et al.*, 2008; Harrison, 2009; Bell *et al.*, 2011; Timilsina *et al.*, 2011; HLPE, 2013a; Gasparatos *et al.*, 2015). The other anticipated benefits are increased energy supply and creating outlets for agricultural products while stimulating the rural economy. The anticipated additional rural income benefits generated are considered as some of the direct links to reducing rural vulnerabilities, among others (Thomas & Kwong, 2001; Meyer *et al.*, 2008; Brittain & Lualaba, 2010; Ambali *et al.*, 2011; Mwakaje, 2012).

Critics of biofuels promotion have advanced arguments surrounding the negative externalities, including land tenure insecurity, indirect land-use change and food (in)security concerns, which remain extensively debated issues (Ajanovic, 2011; Mwakaje, 2012; Pradhan & Mbohwa, 2014). Sceptics question the transparency of how long-term land contracts are negotiated with little involvement of other interested parties like civil society (Molony & Smith, 2010). Extreme views have branded these initiatives as 'land grabbing' while others have called it 're-colonization of African land' (Cotula & Vermeulen, 2009; Havnevik, 2011; Matondi *et al.*, 2011; Acheampong & Campion, 2014). The threat to food security, especially for net food importing economies, has also been highlighted (Cassman & Liska, 2007; Harrison, 2009; Rajagopal *et al.*, 2009; Headey *et al.*, 2010; Cheteni, 2017). Nevertheless, others argue that a delicate balance exists within certain thresholds that limit the carbon debt, depending on types of feedstock and production practices used (Romeu-Dalmau *et al.*, 2016; Schuenemann *et al.*, 2016)

The biofuels potential in sub-Saharan Africa (SSA) is relatively large as compared to North Africa. The favourable agricultural climate for most arable crops gives SSA an agroecological advantage, which in North Africa may be limited to semi-arid tolerant plants like *Jatropha*

curcas (*J.curcas*) (Cotula *et al.*, 2008; Cotula & Vermeulen, 2009; Taheripour *et al.*, 2009; Lashitew, 2011). von Maltitz *et al.* (2018) suggest that integration of smallholders in the biofuels value chain in southern Africa seems to be driven more by the rural development hypothesis than other agendas (such as energy security and climate change). The anticipated livelihood impacts of biofuels development hinges on agricultural production being rural-based (Solomon, 2010). Arguably, biofuel's contribution to rural incomes will only occur when its growing demand leads to gains in technological innovations and resource productivity and increased utilization of underutilized productive resources (such as land and labour) (Pingali *et al.*, 2008).

Land tenure security concerns raised by stakeholders due to biofuels promotion (Matondi *et al.*, 2011) suggest that the out-grower biofuel business model is likely to be a more plausible option for smallholders than for smallholders plantations (von Maltitz & Setzkorn, 2013). The out-grower business model enlists the smallholders as landowners to produce the feedstock on their land (German *et al.*, 2011) and sell it to biofuel processing companies. Despite the collapse of many previous biofuel projects across Africa (mostly industrial plantations), a few *Jatropha* projects survived, like the case of some plantations in Mozambique and out-grower schemes in Malawi (Gasparatos *et al.*, 2012; von Maltitz *et al.*, 2014; von Maltitz *et al.*, 2016). Smallholders in Malawi in some districts grow *Jatropha curcas* as a complementary, high-value tree crop for biofuels production¹ (Makungwa *et al.*, 2013; Wiyo & Banda, 2014). *Jatropha curcas* is a hardy deciduous crop with low water use (Everson *et al.*, 2013). These smallholders have diversified into growing energy crops from traditional crops (such as cereal, legume, roots and tubers) in a predominantly food-cash crop agricultural system (Government of Malawi, 2013).

1.2 Livelihoods, shocks, and smallholder biofuel production in Malawi

Malawi is a Southern Africa Development Community (SADC) member state considered with potential for increasing biofuels production (Thomas & Kwong, 2001; Jumbe *et al.*, 2009; Watson, 2010). Agriculture plays a significant role in the economy of Malawi. It contributes up to a third of the country's gross domestic product and employs over 60% of the total labour

¹ The biofuel from *Jatropha* seeds is produced for domestic blending with diesel up to 8% and in paraffin used for lightening (Government of Malawi, 2013).

force (NSO, 2014; Government of Malawi, 2018a). The structure of Agriculture in Malawi is dualistic, comprising of the smallholder and estate sectors, producing mostly food crops on customary land and cash crops on leasehold land, respectively (Malawi Government, 2018). Arable crop farming is a primary source of livelihood, complemented by livestock rearing in most rural areas of the country. Tobacco is the country's leading foreign export commodity. The industry alone contributes over 40% in export revenues, making it vulnerable to external shocks and the most tobacco-dependent economy in the world (Otañez *et al.*, 2009; Government of Malawi, 2018a). Other cash crops include tea, groundnuts, and coffee. Maize is the country's primary staple food and a significant food security crop, with an average of 1.67 million hectares harvested annually in the last decade (FAOSTAT, 2018). Malawi has one of the highest maize percentage area to cereal area (89%) and per capita consumption (143kg/year) in Africa (Smale & Jayne, 2003). The long term negative market trends for tobacco (caused by the anti-smoking lobbies), and an overemphasis on maize in the agricultural policy discourses, are the major motivation for prioritising production diversification as well as exports in the Malawi National Agricultural Investment Plan (NAIP) (Malawi Government, 2018).

The smallholder agriculture sector plays an essential role in the livelihoods of the majority of the population, who are primarily rural dwellers (84%) and to the economy of Malawi (National Statistical Office (NSO), 2018). Given the vital role and size of the smallholder agricultural sector, as is the case in most developing countries, the industry policies have significant implications for the country's social and economic trajectories (Lora *et al.*, 2011; Fan *et al.*, 2013).

Like most countries in southern Africa, the smallholder sector is affected by a myriad of challenges which range from natural shocks (weather-related) to human-made shocks (market failures, price volatility, etc.) (World Bank, 2007; Saldarriaga Noel *et al.*, 2020). Weather variability, inconsistent rainfall, in particular, is one of the sources of vulnerability in predominantly agricultural-based economies (Demeke *et al.*, 2011). Reliance on a single annual harvest of rain-fed maize crops for daily calorie intake for the rural population impacts on food and nutritional security (ICEIDA, 2012). In 2015, this condition caused a decline in the production of all major sources of starchy carbohydrates such as maize (30%), rice (18%) and cassava (2%) (Government of Malawi, 2016a). Agricultural systems need to adapt to these

changes for them to be more resilient by transforming practices, diversification of the enterprises and crop species (Di Falco *et al.*, 2011; Kankwamba *et al.*, 2018).

The Malawi government is a signatory to international statutes such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (Government of Malawi, 2016b). The parties to these statutes are encouraged to enact laws, design legislative frameworks and implement adaptation strategies to address unfavourable impacts caused by climate change. The Malawi Government Growth and Development Strategy (MGDS) III and its predecessor MGDS II policy documents outlined, among other strategies, the increased use of renewable energy sources, increased agricultural productivity and diversification as its key priority areas (Government of Malawi, 2012b; Government of Malawi, 2017). Biofuels production delivers on two of the above objectives as renewable energy sources and crop diversification (Government of Malawi, 2013; Romeu-Dalmau *et al.*, 2016).

Crop diversification involves the choice of different crop species, including planting energy crops like *Jatropha curcas* for biofuels production (Wale, 2010; Government of Malawi, 2013). In the early 2000s, the BioEnergy Resources Limited company (BERL) promoted *Jatropha curcas* cultivation in hedge-rows and on marginal lands to buy the *Jatropha curcas* seeds for processing biofuels. Biodiesel production in Malawi is still in its infancy, while the country has a globally recognised long track record of a prosperous bioethanol industry (Johnson & Silveira, 2014).

Malawi has consistently blended fossil fuel with bioethanol from sugarcane molasses since the 1980s, while biodiesel blending followed only recently. The government has supported ethanol-petrol blending programmes since 1982 (Thomas & Kwong, 2001). Two major private companies, namely Presscane and Ethanol Company (ETHCO), with an annual production of 30 Million litres from molasses, produce bioethanol for the domestic and export markets (Jumbe *et al.*, 2009). The price for bioethanol is set slightly below the landed cost of imported petroleum by 5%, deliberately incentivising petroleum importing companies to use ethanol in blending with petrol (Government of Malawi, 2009). Currently, biofuels contribute only 4% of transport fuel produced domestically, blended at 20:80 and 9:91 for bioethanol and biodiesel, respectively (Government of Malawi, 2018b). The extensive cultivation of *Jatropha curcas* for

biofuels production only gained momentum much later (the early 2000s). *Jatropha curcas*² is one of the biofuel crops that gained prominence due to its many attributes such as (i) its low management requirements, (ii) adaptability to marginal lands, and (iii) the fact that it is not a food crop. These attributes led to the creation of ambitious targets in developing countries to attract foreign investors. Most governments in sub-Saharan Africa (SSA) have existing or proposed biofuel blending mandates of up to 20% (Jumbe *et al.*, 2009; Sparks & Ortmann, 2011; Jumbe & Mkondiwa, 2012; Gasparatos *et al.*, 2015). Smallholders' participation in the biofuels value chain is in feedstock production either as wage earners (in industrial plantations) or as out-growers selling feedstocks to biofuel companies (Achten *et al.*, 2008; Achten *et al.*, 2010). *Jatropha curcas* can be cultivated as a monocrop (as in plantations) or as hedgerows around farmsteads and homes. Traditional uses of *Jatropha curcas* never warranted the application of scientific knowledge to improve the economic importance of the crop; to a considerable extent, it has been promoted as a developmental crop with untapped potential (Brittaine & Lualaba, 2010). A recent study also reported positive gains in carbon sequestration from *Jatropha curcas* hedge-rows from BERL operational areas in Malawi (Romeu-Dalmau *et al.*, 2016).

Currently, the Malawi government does not have a specific biofuels policy. The recently revised government of Malawi's energy policy asserts its broader policy position, which seeks to "ensure adequate production and supply of petroleum and biofuels at affordable prices" (Government of Malawi, 2018b:9). Nalivata and Maonga (2011) comment further that energy law only mentions biofuels as a source of energy in the energy mix. However, a relevant policy or legal framework targeted at biofuels is still non-existent. The Malawi Bureau of Standards, with technical support from United Nations Energy Programme (UNEP) and United Nations Development Programme (UNDP), has also developed biodiesel standards to regulate minimum product requirements (Malawi Government, 2011; Malawi Bureau of Standards (MBS), 2012). Malawi already has ethanol standards in place (Malawi Bureau of Standards (MBS), 2007).

² *Jatropha curcas* is a tropical oil-seed tree crop which grows well in low altitude areas (0 to 500m) and tolerates moderate annual rainfall conditions (300 to 1,000mm). The seeds have a high oil content which can be extracted and used as a straight vegetable oil or blended with fossil fuel (paraffin or diesel) to make biofuels (Achten *et al.*, 2008; Makungwa *et al.*, 2013).

1.3 Problem statement and justification

The need to increase agricultural productivity as a strategy to uplift the welfare of smallholders is widely recognised. Nonetheless, the complexity of heterogeneity among smallholders has rendered previous agricultural interventions less effective because to some extent. Stakeholders (donors, government and NGOs) have designed and implemented ‘blanket’ packages and recommendations (interventions, targeting, extension messages) (Kamau *et al.*, 2018; Cele & Wale, 2020). While smallholder farmers’ needs are generally similar, the ‘blanket’ recommendation made for such a diverse population has not yielded appropriate responses and expected outcomes (Snapp *et al.*, 2003; Wale & Yalew, 2007; Makate *et al.*, 2018a). Agricultural systems research describes a farming system as the totality of all the household's unique production and consumption decisions. Every household decision-making unit is different from another, which suggests a need for novel solutions to address the constraints (Köbrich *et al.*, 2003). A practical way of addressing the heterogeneity in smallholder farming systems is to classify or group homogenous households into clusters based on their similarities (such as resource endowment, enterprise choice, experience, etc.).

While previous studies have been conducted to characterise smallholders in Malawi, the focus has been on analysing diversity in technology use (soil fertility, crop protection) on food crops and efficiency of farming operations (Orr & Jere, 1999; Kamanga, 2011; Mponela, 2016; Berre *et al.*, 2017). von Maltitz and Setzkorn (2013) also evaluated a typology of the feedstocks in biofuel projects in the southern Africa region, which included Malawi. The study described, among others, types of feedstocks and the smallholder out-grower business model arrangement, where smallholders received technical support and supply biofuel companies with feedstock. To the author's best knowledge, no study in Malawi applied typologies to analyse the heterogeneity among smallholders, energy crop producers and compared them in a food-cash crop production system. Considering that biofuels production has the potential to contribute to climate change mitigation and rural economies, it is important to understand and characterise the specific constraint and opportunities for targeting interventions for livelihood improvement.

Combating food insecurity is one of the top priorities for the Malawian government. The Malawi MGDS III policy document articulates the government’s vision to build a productive,

competitive, and resilient economy. It underscores the government's aim and commitment to combat rural poverty and hunger to increase resilience to food insecurity (Government of Malawi, 2012b; Government of Malawi, 2017). The government and development partners' sponsored farm inputs subsidy programme (FISP) (fertiliser and improved seed), administered through a coupons system to targeted beneficiaries (Chibwana *et al.*, 2010; Lunduka *et al.*, 2013; Ricker-Gilbert *et al.*, 2013), coupled with good weather, has helped to contribute to reducing food insecurity in the country (Juma, 2011). However, since food prices have been comparable to import parity levels during most lean seasons, Malawi has almost continuously imported maize during these periods, suggesting that the production effect of FISP was insufficient to displace imports (Ricker-Gilbert *et al.*, 2013). The empirical evidence also indicates that the impact of FISP on local food prices or wages were either small or absent (Jayne *et al.*, 2018). The Affordable Inputs Program (AIP) has since replaced the predecessor FISP with a few modifications. The later AIP replaced the coupon system with a biometric 'general subsidy' targeting 4.2 million smallholders costing the government K160.2 billion. The smallholders will access two bags of 50 kilograms of fertilizers and five kilograms of certified seed at subsidized prices of K4,495 and K2,000, respectively (Chilundu, 2020a).

Nonetheless, others have branded the subsidy programme as an inefficient use of public funds and unsustainable food security strategy (Sauer & Tchale, 2009; Saldarriaga Noel *et al.*, 2020), which burdens the national budget (Headey & Fan, 2010). The civil society decried that the AIP, at 45% of the agriculture budget, skews the country's effort towards food security over other priorities at the ministry (Chilundu, 2020b; Chilundu, 2020a). Instead, others have suggested that government should be encouraged to support infrastructure development to open up remote areas and stimulate demand for agricultural outputs (Sauer *et al.*, 2006; Tchale & Sauer, 2007; Sauer & Tchale, 2009). Budgetary constraints also entail that only a few households can benefit, and limited quantities of the subsidised inputs are accessed. However, there is a consensus that the Malawi government needs to improve efficiency and confront the thorny issue of the subsidized inputs programme's long-term sustainability (Lunduka *et al.*, 2013; Malawi Government, 2018; Saldarriaga Noel *et al.*, 2020). Reforms in future FISP, which are cost-effective and increase smallholders' resilience to climate change through diversification from continuous cereal mono-cropping, have been proposed (Jayne *et al.*, 2018).

Despite the Malawi government making some strides to alleviate food insecurity more recently, the problem persists. Furthermore, information on the factors that affect susceptibility to food

insecurity remains somewhat limited (Pankomera *et al.*, 2009; Kakota *et al.*, 2015). The government's energy policy promotes the integration of smallholders (especially women) in the biofuels value chain (as feedstock producers), which contributes to crop diversification efforts and increasing renewables in the energy mix (Government of Malawi, 2013; Government of Malawi, 2018b). Since low or high household resilience to food insecurity increases or decreases the vulnerability to food insecurity, it is pertinent to investigate which population segments have low resilience levels and the socioeconomic factors affecting resilience to food insecurity.

Previous studies have analysed smallholders' food insecurity from a vulnerability perspective (Chaudhuri *et al.*, 2002; Bogale, 2012; Kakota *et al.*, 2015; Klasen *et al.*, 2015). A new and growing literature applies an alternative approach of resilience to food insecurity (Alinovi *et al.*, 2010; Ciani & Romano, 2014; Gambo Boukary *et al.*, 2016). As applied in the current study, the resilience concept shifts the focus from long-term equilibria to creatively address system capacity to manage the effect of short-term perturbations and disturbances (Alinovi *et al.*, 2010). Daie and Woldtsadik (2015) argue that vulnerability and resilience are determinants of each other. To the author's best knowledge, no empirical study has investigated the impact of *Jatropha curcas* cultivation on resilience to food insecurity among smallholders, using robust econometric techniques.

Empirical studies have also not adequately investigated the impact of *Jatropha curcas* cultivation on welfare among smallholders in the sub-Saharan Africa region, including Malawi. There are few studies in Malawi that investigated smallholders' biofuels linkage to food security and livelihoods. The previous studies conducted on *Jatropha curcas* have focused on areas like policy, awareness, small-scale processing, adoption, and socioeconomic impacts, among others (e.g. Jumbe *et al.*, 2009; Mponela *et al.*, 2011; Nalivata & Maonga, 2011; von Maltitz *et al.*, 2014; Gasparatos *et al.*, 2015; Mudombi *et al.*, 2016; von Maltitz *et al.*, 2016). The literature on socioeconomic impacts of biofuels cultivation at the local level has largely remained theoretical, qualitative and has not addressed sample selection bias (Hodobod & Tomei, 2013; Mudombi *et al.*, 2016). Farmers can self-select or stakeholders target interventions to specific areas, potentially causing selection bias. A quantitative study on the impact of *Jatropha curcas* cultivation on smallholders' livelihoods that addresses sample selection bias in Malawi has not previously been conducted. Failure to account for selection bias in the estimation of outcomes might lead to under-or overestimation of the effects of

biofuels promotion at the local level. With the publicity of the promise of biofuels to deliver on the rural development agenda, a robust econometric investigation into the welfare impacts of *Jatropha curcas* cultivation is well justified (Ewing & Msangi, 2009; Ambali et al., 2011; Herrmann et al., 2017).

Apart from generating policy and management relevant information for Malawi, as the country progresses forward with its interest in exploiting the economic benefits from promoting biofuels, the current study contributes to the general pool of knowledge on the interaction of livelihoods biofuels and smallholder food security. The empirical evidence from the rigorous quantitative analysis may be relevant for similar settings other than the study area, especially in developing regions. Following the above, this study is set out to address the objectives formulated in the following section.

The contribution of growing energy crops in Malawi to creating a resilient and robust rural society is still not known. This knowledge is critical to ascertain whether current agricultural practices used in growing energy crops impact livelihood outcomes like food security.

1.4 Research objectives

The study's general objective was to examine smallholders' heterogeneity and the economic impact of *Jatropha curcas* cultivation on farmers' welfare in the Mangochi District of Malawi. This was achieved through the following specific objectives:

The specific objectives were to:

- i. identify sources of smallholder heterogeneity and farmer typologies of *Jatropha curcas* producers to inform livelihood improvement interventions.
- ii. assess the effect of *Jatropha* cultivation on household resilience to food insecurity in Mangochi District, Malawi
- iii. evaluate the welfare impacts of *Jatropha curcas* cultivation among smallholders in southern Malawi.

1.5 Outline of the thesis

The thesis adopts the format of individual papers. The thesis has been organised into six chapters: introduction, literature review, three empirical chapters, and a conclusion. The rest of the five chapters are organised as follows.

Chapter 2 presents the fundamental definitions of terms and concepts used in this study, followed by a review of the relevant literature that sets the empirical chapters' background.

Chapter 3 investigates sources of smallholder heterogeneity and farmer typologies for *Jatropha curcas* producers to inform livelihood improvement interventions.

Chapter 4 assesses the effect of *Jatropha* cultivation on household resilience to food insecurity in Mangochi District, Malawi.

Chapter 5 focuses on the welfare impacts of *Jatropha curcas* cultivation, which also accounts for both observable and unobservable sources selection bias.

Chapter 6 provides the study conclusions drawn from the findings of the study discussed in the empirical chapters. Study limitations and suggestions for further research are presented last.

Chapter 2: A literature review

2.1 Definition of Concepts and Terminologies

2.1.1 Heterogeneity among smallholders

Heterogeneity captures the uniqueness, diversity, and variations among smallholders in various aspects such as composition, farming experience, assets, and livelihood strategies. Numerous factors cause heterogeneity. The factors that cause heterogeneity among smallholders are not necessarily static but are continuously evolving (Tittonell *et al.*, 2010). Thus, smallholders comprise a diverse set of households that are not affected in the same way by constraints in their pursuit to undertake potentially profitable activities in the agricultural sector (Köbrich *et al.*, 2003; Fan *et al.*, 2013). The variations in agroecological terrains, weather conditions, edaphic factors, and the socioeconomic environment inform smallholder livelihood strategies and trajectories. The development domain (agro-ecological potential, market access, and population density) concept has been used to analyse the constraints and opportunities for agricultural production investments (Pender *et al.*, 2004; Kruseman *et al.*, 2006). Agroecological potential (moisture-rainfall, soil and temperature) has been used in the geographical demarcation of absolute agricultural potential in various areas, including Malawi (Chamberlin *et al.*, 2006; Chinsinga, 2008b). Market access (distance to outlets, infrastructure, ICTs) turns absolute potential into a comparative advantage, separating two similar locations (Chamberlin & Jayne, 2013). Population density is the demographic dividend related to the comparative labour advantage and demand for goods and services (Pender *et al.*, 2004). However, development domains are best suited as first-order filters to identify broader constraints and opportunities for rural development. Lower level-specific interventions require going beyond development domains to identify the specific interventions, commodities or technologies for livelihood improvement (Pender *et al.*, 2004).

Chapter 0 provides empirical evidence on heterogeneity and the implications on opportunities and constraints to livelihood improvement for smallholders and energy crop producers. Accounting for the heterogeneity in smallholders makes it possible to identify a means to group or classify to maximise their homogeneity within typologies and heterogeneity between the groups (Köbrich *et al.*, 2003).

2.1.2 Resilience to food insecurity

Resilience to food insecurity is the capacity that ensures that shocks and stresses do not have protracted adverse developmental effects (d'Errico & Di Giuseppe, 2018). Food insecurity can be analysed using the vulnerability or resilience concept. Though related in some aspects, these two concepts should not be confused as the same (Cutter, 2016). Generally, vulnerability analysis aims at predicting the occurrence of a future risk such as poverty and food insecurity (Hoddinott & Quisumbing, 2003; Bogale, 2012).

Daie and Woldtsadik (2015) contend that the vulnerability approach presents the agents (households) and their role as relatively passive, while resilience puts the household and their responses to stressors at the centre stage. Smallholders make rational decisions *ex-ante or ex-post* a shock-encounter that affects resilience capacity and livelihood outcomes such as food security (d'Errico *et al.*, 2018; Ansah *et al.*, 2019). This study adopts the resilience approach because it focuses on assessing the capacity of the household as a decision-making unit to manage the effects of shocks (d'Errico *et al.*, 2018).

2.1.3 Welfare impact evaluation of rural development programmes

Welfare impacts can be defined as outcomes resulting from engaging in strategies, activities, interventions, or innovations designed to achieve a higher hierarchical developmental goal, such as food and nutrition security. The various measures used in empirical studies to capture welfare impacts include, but are not limited to, poverty (incidence, depth, or severity), income, food security indices (Oluyole *et al.*, 2009; Akerele *et al.*, 2013), anthropometrics, dietary diversity (Upton *et al.*, 2016), duration of self-sufficiency (Negash & Swinnen, 2013), calorie consumption (Nyariki *et al.*, 2002) and consumption expenditure (Asmah, 2011; Asfaw *et al.*, 2012b; Sinyolo *et al.*, 2014a; Ahmed *et al.*, 2017). Analysts in some studies use a combination of different welfare measures to exploit the various merits of the selected methods to increase the robustness of their findings (Negash & Swinnen, 2013; Sinyolo *et al.*, 2014a; Nguyen *et al.*, 2015).

Chapter 5 presents empirical evidence on the welfare impacts of *Jatropha curcas* cultivation, which applied robust econometric techniques to account for sources of selection bias. This

study used a combination of poverty indices and robust econometric methods to evaluate the welfare impacts.

2.3 The biofuels outlook: A review of global and domestic trends, claims and evidence

2.3.1 Global biofuels production trends

The three key players in the global biofuels industry for the last decade are the United States of America (USA), Brazil, and the European Union (EU) (Tokgoz *et al.*, 2008; Al-Riffai *et al.*, 2010; Solomon, 2010; Gustafson, 2012; REN21, 2019). More recently, China, Argentina, Thailand and Indonesia have shown progressive growth (Headey & Fan, 2010; Bell *et al.*, 2011; Rouhany & Montgomery, 2019). The top two major bioethanol producing countries accounted for 84% of the global ethanol production in 2018. The USA is the largest single-country producer of bioethanol, contributing up to 54% (60 911 million litres) of total 2018 production, followed by Brazil at 29%. China is an emerging player in the market and contributes 4% to global bioethanol production. Interestingly, India, Argentina and Thailand are the only developing countries to register at least 1% of the leading ethanol producers (Table 1).

Table 1 Recent production estimates for the top producers of bioethanol and biodiesel, 2018 (billion litres).

Country	Ethanol	Percentage	Biodiesel	Percentage
United States	60.9	54%	9.1	20%
Brazil	33	29%	5.4	12%
China	4.1	4%	1	2%
Canada	1.9	2%	0.4	1%
Thailand	1.5	1%	1.6	4%
India	1.4	1%	0.2	0%
Argentina	1.2	1%	2.8	6%
Germany	1	1%	3.5	8%
France	0.9	1%	2.2	5%
Spain	0.5	0%	2.5	6%
United Kingdom	0.5	0%	0.5	1%
Netherlands	0.3	0%	1.8	4%

Country	Ethanol	Percentage	Biodiesel	Percentage
Poland	0.2	0%	1	2%
Indonesia	0.1	0%	4	9%
Italy		0%	1.4	3%
EU-28	4.4	4%	7.9	17%
World total	111.9	100%	45.3	100%

Note: Data on EU-28 exclude major producers in the EU bloc such as Germany, France, Spain, Italy, Netherlands, Poland and the United Kingdom.

Source: REN21 (2019).

Recent trends show that the USA and Brazil are the top two biodiesel-producing countries contributing 20% and 12 % respectively of the 2018 output (45 300 million litres). In the EU, major biodiesel producing countries are Germany (8%), Spain (6%) and France (5%). Africa is not on the top list of producers for both biodiesel and bioethanol (see Table 1) (Rajagopal & Zilberman, 2007; REN21, 2019).

Corn is the primary feedstock for US bioethanol, while Brazil uses sugarcane (Senauer, 2008; Tokgoz *et al.*, 2008; RFA, 2020). The EU uses various feedstocks and is a net importer of bioethanol, while the rest (China, Canada, etc.) use a combination of wheat, cassava, and sweet sorghum (Dallemand & Vignali, 2008). Rapeseed is the most significant biodiesel feedstock in the EU, while the USA relies on soybeans as the principal feedstock in biodiesel production (Yeboah *et al.*, 2012). Though Malaysia is not part of the top biodiesel producers, combined with Indonesia, they are emerging giants in palm oil biodiesel production in the East Asia region (Cotula *et al.*, 2008; Rouhany & Montgomery, 2019). In Latin America, Argentina expanded its soybean biodiesel programme to be among the top global biodiesel producers, coming third in the region after the USA and Brazil when compared at country level (see Table 1) (Janssen & Rutz, 2011; Licht F.O., 2018). Other feedstocks such as *Jatropha curcas* and coconut oil account for a tiny proportion of global biodiesel production. *Jatropha curcas* is an essential feedstock in the biodiesel programme in India, South East Asia and other African countries, including Malawi (von Maltitz & Setzkorn, 2013; von Maltitz *et al.*, 2016; Rouhany & Montgomery, 2019).

Data from F.O. Licht, compiled by the Earth Policy Institute (2012) and REN21 (2019), show steady and sustained growth in global trends of bioethanol production from 1975 until the late

1990s. After a slight decline in production between 1997 and 2000, global output in the following decade has shown a steep ascent on account of progressively increasing demand from mandates in the Renewable Fuel Standards (RFS) (Licht F.O., 2018; Congressional Research Service, 2020). Data on biodiesel exhibit a similar pattern to bioethanol (see Figure 1 below). The main reasons for the increase in production for the recent period have been attributed to a combination of geopolitical factors, environmental concerns on greenhouse gas (GHG) emissions, and high and volatile crude oil prices (Elobeid & Hart, 2007; Tokgoz *et al.*, 2008; Chakauya *et al.*, 2009; HLPE, 2013a).

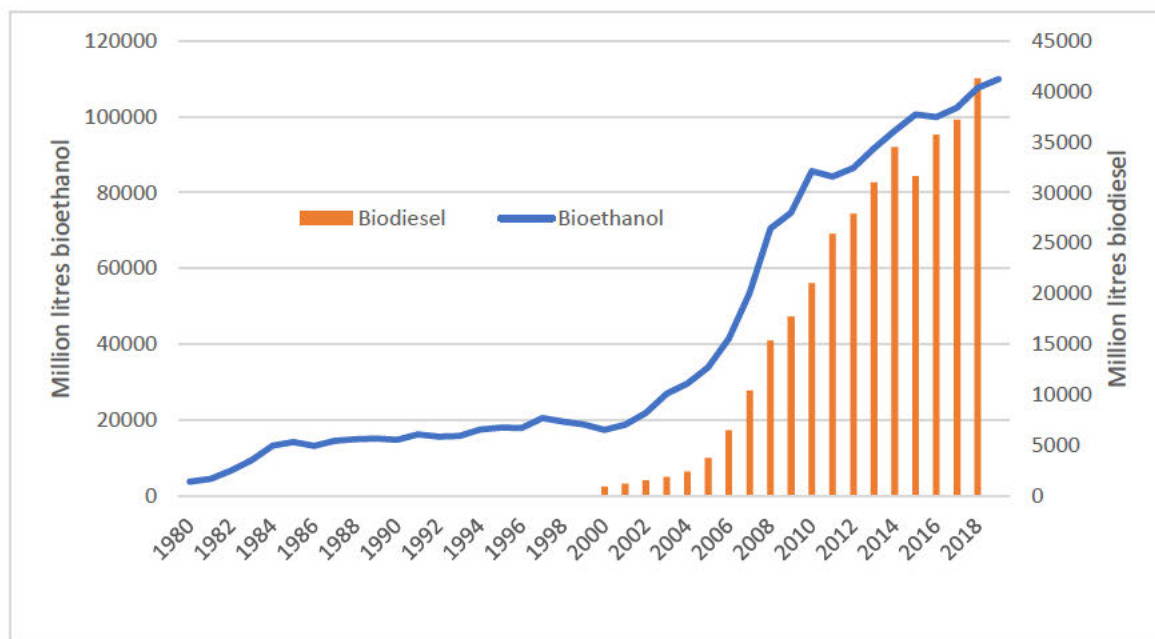


Figure 1.0 Global trends in Bioethanol and Biodiesel production, 1980 to 2016.

Source: Earth Policy Institute (2012), REN21 (2018); REN21 (2019).

The USA is the largest single contributor to the North American bloc's bioethanol and biodiesel production (Earth Policy Institute, 2012; REN21, 2019). The region exhibits a general growing trend for annual ethanol production (million litres annum⁻¹) for the period 2006 to 2016 (9%) (Table 2). In 2018 the USA (54%) and Brazil (30%) jointly accounted for the bulk (84%) of the total world bioethanol production (RFA, 2020). Biodiesel production increased by a much larger proportion (65%) during the same period in the region because of expansions in national biodiesel programmes in Argentina and Brazil (Table 2). While both Argentina and Brazil use soybean as a feedstock, the biodiesel industry in Argentina has a strong export orientation, whereas Brazil has a robust domestic market (Naylor & Higgins, 2017). As such, Argentina is

vulnerable to market trends, changes in trade policies, tariffs, etc., on the international market (Licht F.O., 2018).

For the last two decades, the USA has been a net importer of biodiesel and bioethanol. Therefore, domestic mandates on biofuels have affected demand in the exporting countries (Brazil, Canada, and Argentina). The drop in production and consumption of biofuels in 2009 was associated with the expiry of tax credits. The USA's RFS, which the Environmental Protection Agency (EPA) manages, requires increasing amounts of renewable fuels to be blended in transport fuels since their inception (2006). The statutes targeted 4 billion gallons of renewable fuels in 2006, increasing progressively to 16.28 billion gallons in 2014 and 36 billion gallons in 2022. The EPA has been given the responsibility to set future targets (Congressional Research Service, 2020). The main challenges facing the EPA in fulfilling its mandated obligations have been the heavy scrutiny of its regulatory work (by Congress). There have also been various industry litigations mainly due to uncertainty in policy targets, which have slowed growth (production & refinery capacity) in advanced (second generation) biofuels. As such, the industry has relied on biodiesel to meet mandates (Naylor & Higgins, 2017).

Table 2 World ethanol and biodiesel production by region (million litres), 2012 to 2016

Region	Product						%
		2012	2013	2014	2015	2016	Change
Africa	Biodiesel	8	7.5	8.1	79.6	164	1921%
	Ethanol	419	446	481	517	567	35%
EU	Biodiesel	11 282	12 318	14 597	14 070	13 652	21%
	Ethanol	3 957	4 183	4 056	4 404	4 392	11%
Eurasia	Biodiesel	263	238	255	210	209	-20%
	Ethanol	678	684	600	652	667	-2%
Asia &	Biodiesel	6 046	7 191	7 447	5 474	7 897	31%
Oceania	Ethanol	4 084	4 707	4 775	5 405	6 105	49%
Middle East	Biodiesel	0	0	0	0	0	0%
	Ethanol	26	28	30	31.9	30	15%
North	Biodiesel	3 849	5 247	5 123	5 066	6 336	65%
America	Ethanol	53 881	54 317	58 075	59 213	58 531	9%
Central & South America	Biodiesel	6 332	5 844	7 051	6 654	7 191	14%
	Ethanol	23 320	26 920	27 736	29 914	29 170	25%

Source: Adapted from U.S. Energy Information Administration (EIA) (n.d).

The trends in European biodiesel production, mainly from rapeseed, has been growing steadily, increasing by 21% between 2006 and 2016. Nonetheless, new developments in the revised EU's Renewable Energy Directive (RED II) No. [2018/2001/EU](#), which seeks to make Europe the first climate-neutral continent by 2050, are likely to map new trajectories in the biofuels market. The EU plans to decarbonise the economy in line with the 2015 Paris Climate Change Agreement. Among other strategies, the RED II targets for 2030 propose a cap on the first-generation biofuels to 7% and increasing advanced biofuels (biofuels from sources other than corn) to 3%, which have already been ratified by others (Italy). The RED II adopted stringent environmental conditions on GHG reduction, which requires, among others, that all renewable fuels provide 50% less GHG emissions compared to fossil oils. These changes are a cause of uncertainties and will likely reshape the prospects in the EU biofuels market. The new regulations put soy biodiesel from Argentina at risk of exclusion from the EU market (Naylor & Higgins, 2018; REN21, 2018; European Commission, 2019; REN21, 2019). The global trade

for bioethanol and biodiesel has also been impacted by protective import taxes and quotas introduced in several countries. For example, Argentina capitalised on the anti-dumping laws in the EU on USA soybean biodiesel to increase exports in the regions and competitiveness during the embargo. The USA's 'anti-dumping' suits at the World Trade Organisation (WTO) on imports from Argentina and Indonesia are likely to reduce future demand in these markets (Naylor & Higgins, 2018).

In Asia and Oceania, Thailand and Indonesia are the major players in the biodiesel industry, jointly contributing about 16% to global output. In comparison, India contributed only 0.2 billion litres (<1%) of the total 2018 world biodiesel output from the region (Table 1). The rise of Indonesia and Thailand in biodiesel output is due to expansions in palm oil production. Thailand invested in the growth of its palm oil sector for the domestic market. In contrast, Indonesia becomes one of the leading exporters of crude palm oil (CPO) to the EU (Naylor & Higgins, 2017). The stringent environmental conditions in the RED II pose a threat to CPO exports from the region. The GHG from CPO produced from the peat-rich regions in Asia due to direct land-use change (LUC) and indirect land-use changes (ILUC) is on the higher side (2.8-19.7kgs CO₂ equivalent per kg CPO) (Reijnders & Huijbregts, 2008). Although China is a distant third-largest producer of bioethanol, in terms of volumes globally (4%), new investments to increase production capacity have been rising to meet its domestic blending mandates. For example, despite new global investments in new biofuel production capacity dropping by 8% in 2018 compared to the previous years, production capacity in the developing world led by China was on the rise (REN21, 2018; REN21, 2019). India and Thailand have also emerged in the last decade to be among the top 10 leading bioethanol producers, with a combined output of slightly over 2,900 million litres in 2018 (Table 1) (REN21, 2016; REN21, 2019; U.S. Energy Information Administration (EIA), n.d).

Data on Africa generally indicate a stagnating growth for both bioethanol and biodiesel production. Notably, Africa's figures presented in Table 2 are relatively low for bioethanol and biodiesel compared to other regions like Asia and Oceania. Overall, current statistics rank Africa's contribution to current trends as low (Table 2). Nonetheless, various simulation model results using Computable General Equilibrium (CGE) and IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) projected increases in biofuels production for Africa in future, with mixed results on macroeconomic variables and food security (Abdulai & Ramcke, 2009; Timilsina *et al.*, 2010; Taheripour *et al.*, 2011).

Jatropha curcas was the preferred feedstock for biodiesel, while sugarcane and its by-product (molasses) were essential feedstock for bioethanol production in most countries in the SSA region. Other minor feedstocks (sunflower, soybean, sugar beet) were mostly under the experimental phase in countries like South Africa and Zambia (von Maltitz & Setzkorn, 2013). While most developing countries set ambitious plans in their biofuels strategies, the reality is that resource constraints crippled their implementation due to their inability to support financial instruments like tax credits (OECD/FAO, 2012). Furthermore, the OECD/FAO (2012:94) argues that “an export-oriented biofuels industry strategy does not develop anywhere, ” suggesting that predictable domestic demand is more sustainable than an export-oriented strategy.

The performance of various start-up biofuel ventures in most SSA countries was generally low, while in countries with older biofuel processing investments before the boom in the 2000s also produced mixed results. Various factors explain the dismal performance of once ambitious biodiesel programmes among SSA countries. For example, Rwanda abandoned the \$35 million *Jatropha curcas* based biodiesel programme in 2017, citing ‘poor science’ in the feasibility studies (Sapp, 2017). In Ghana, the discovery of crude oil reserves and political regime change derailed the biodiesel programme. Other reasons for the poor performance were a pessimistic development discourse led by civil society, which cited the loss of livelihoods, unequal distribution of benefits (between producers, local elites, and investors), land conflicts with locals, and environmental concerns (Acheampong & Campion, 2014; Ahmed *et al.*, 2017). Low *Jatropha curcas* yields, unequal risk-bearing arrangements (which disfavoured producers), lack of legal frameworks, unenforceable contracts, and the limited market outlets led to dismal or no-returns to smallholders in Zambia (German *et al.*, 2011; Kunda-Wamuwi *et al.*, 2017).

Malawi is the only country to consistently produce bioethanol from molasses in the SADC regions since the early 1980s. The reliability of an irrigation water source (Lake Malawi) averts climate-induced disruptions experienced at Triangle Ltd in Zimbabwe (Jumbe *et al.*, 2009; Johnson & Silveira, 2014). Zimbabwe decommissioned bioethanol production in 1992 due to drought, which affected sugarcane production. The country later recommissioned in the mid-2000s led by two bioethanol producers (Green Fuel - using sugarcane, and Triangle sugar estate - molasses) (von Maltitz & Setzkorn, 2013; Earth Policy Institute, 2016; Muposhi & Dhurup,

2017; Ziwira, 2019). Overall, outputs are likely to remain below the set targets in national targets, as promising feedstocks like *Jatropha curcas* continue to underperform (OECD/FAO, 2012; Ahmed *et al.*, 2017).

The future outlook for biofuels in Africa rests in investing in proper structures, institutional capacity, scientifically proven technical innovations, sound business models, legal and operational frameworks with a robust monitoring component to avert unintended externalities (Ambali *et al.*, 2011; Ahmed *et al.*, 2017; von Maltitz *et al.*, 2018; Stafford *et al.*, 2019). Contracts with potential investors need to be scrutinised carefully. Appropriate land administration reforms that address ‘*land grabbing*’ or ‘*neoclassical land colonisation*’, displacement, dispossession by potential investors, and improper or ‘no’ compensation claims raised by locals and civil society are required (Chasukwa, 2013; Acheampong & Campion, 2014; Ahmed *et al.*, 2017). The proposed business models should ensure that risk-bearing mechanisms protect the feedstock producers and other stakeholders in the value chain (German *et al.*, 2011). The sustainability of biofuels development needs to ensure safeguards in ecosystems services (livelihoods, environmental, biodiversity, etc.) (Romeu-Dalmau *et al.*, 2016). Benefit-sharing mechanisms along the value chain should address concerns registered from unpleasant past experiences and lessons in previously unsuccessful programmes (Acheampong & Campion, 2014; Ahmed *et al.*, 2017; von Maltitz *et al.*, 2018). The recently signed agreement by the Nigerian government with Chinese-based companies to build their first biofuel production facility in 2018 needs to consider these tenets carefully (REN21, 2019).

2.3.2 Domestic biofuel production trends

Demand for bioethanol has thrived over the years, with the local (ETHCO and Presscane) companies supplying consumers with fuel-grade, portable and rectified ethanol on the domestic markets. Exports to neighbouring East African countries as well as to Zambia, Mozambique and Botswana have been reported (Liwimbi, 2006; UNDP/Malawi, 2007; ETHCO, 2019). Actual production has not grown in line with demand due to the limited availability of feedstocks (See Figure 2 below). PressCane also started importing molasses from Mozambique in 2014 and Zambia from 2018 to supplement Illovo’s stocks. The proportion of imported molasses increased from 11% in 2014 to 29% in 2019, indicating that demand grew faster than the supply capacity at Illovo (Kabanga, 2020).

Bioethanol production is a well-established venture in the backdrop of primarily stable large-scale sugarcane plantation yields (2 million tonnes year⁻¹) and smallholder out-grower schemes (400,000 tonnes year⁻¹). A recent annual report by the Illovo Malawi group showed that the company made 12% more revenue (3,073 million kwachas) in 2019 from molasses compared to the previous year (Watson, 2010; Illovo Sugar (Malawi) plc, 2019). The long-term trends indicate that bioethanol production exhibits sustained growth since its inception in the early 1980s. Recent production statistics for 2019 show that the two companies produced close to 30 million litres (see Figure 2), mostly comprised of fuel ethanol (58%), rectified spirit (30%) and potable alcohol (11%) sold to various sectors (Liwimbi, 2006; Kabanga, 2020; Ndau, 2020). Hand sanitisers are the recent addition to the product lines as the company contributes to the fight against the COVID-19 pandemic (PressCane, 2020).

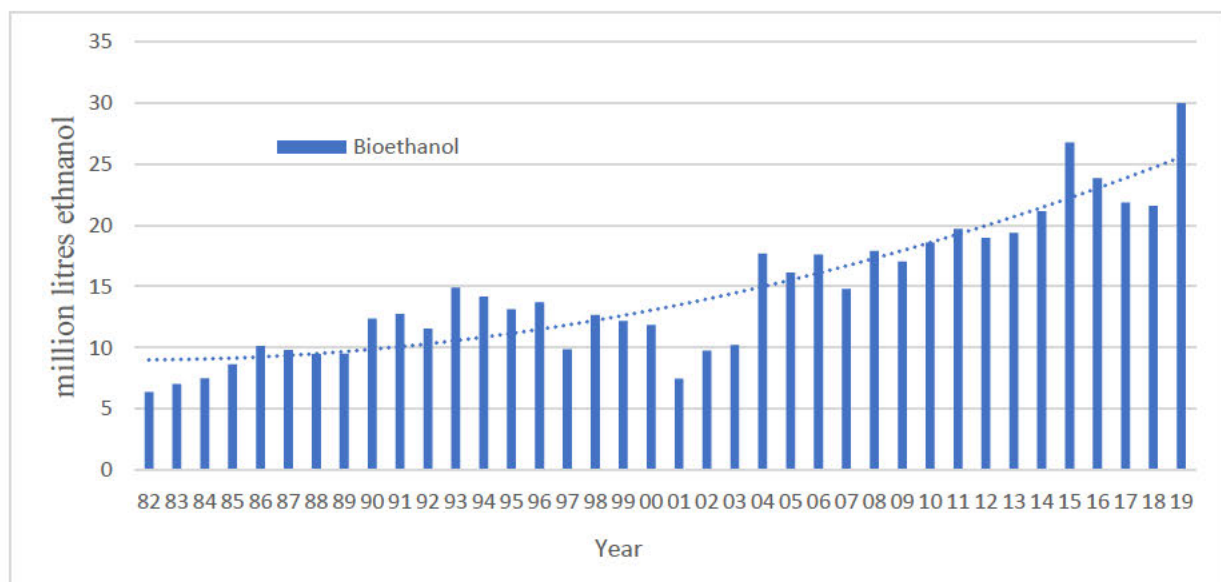


Figure 2.0 Bioethanol production, Malawi, 1982 to 2019.

Source: (Kabanga, 2020; Ndau, 2020).

Conversely, biodiesel production is relatively recent, spearheaded by one company (BERL) and smallholder outgrower schemes. BERL produced only 70,000 litres of biodiesel in 2015 against the backdrop of low *Jatropha curcas* yields but projects an exponential growth in the coming years to 150 million litres target for 2030 (Figure 3) (Malawi Government, 2017). The case of low *Jatropha curcas* yields has been a common phenomenon affecting biodiesel production and has led to the failed venture in other African countries such as Rwanda (OECD/FAO, 2012; Sapp, 2017; Government of Malawi, 2018b).

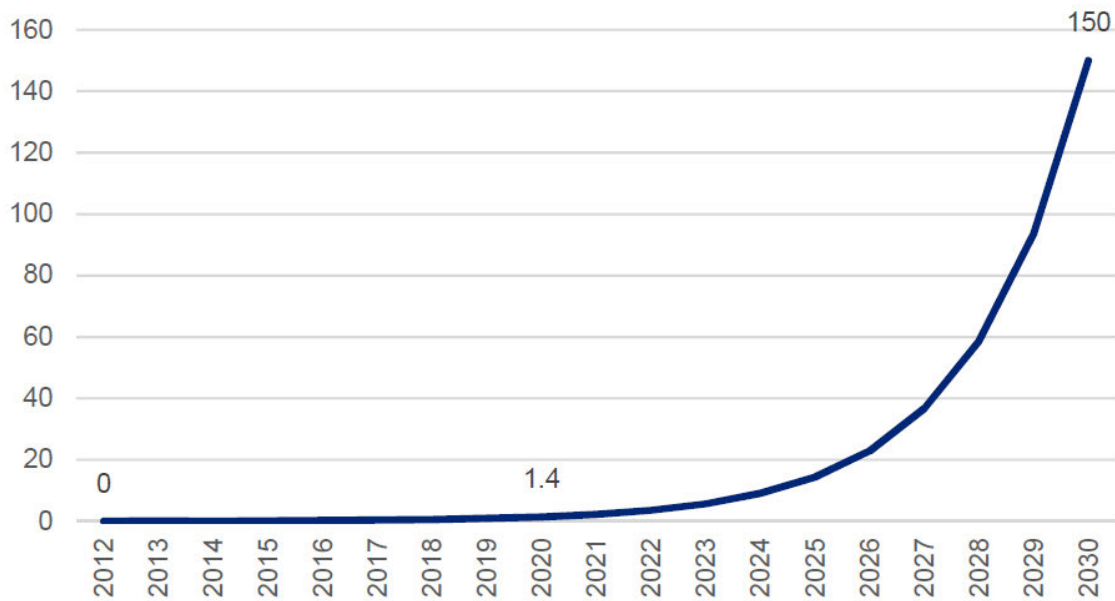


Figure 3.0 Expected biodiesel production of BERL from years 2012 through 2030 (million litres).

Source: (Malawi Government, 2017).

The Government of Malawi supports the blending of ethanol with fossil fuels and has consistently used ethanol in its transport fuel over the last three decades. Blending was not mandatory until 2004, when the government officially enacted the law and designated Malawi Regulatory Authority (MERA) as the regulating body. Bioethanol was priced lower than landed costs of fossil fuel to encourage petroleum companies to use bioethanol. Malawi is an example of a private sector-led initiative with bioethanol production from molasses by two private listed companies (ETHCO and Press Cane Limited) (Jumbe *et al.*, 2009; Johnson & Silveira, 2014). The sole contribution of smallholder farmers to bioethanol production can only be distantly linked through the out-grower schemes since molasses is the primary feedstock (Thomas & Kwong, 2001).

2.3.3 Bioenergy in Malawi

Energy consumption in Malawi is skewed towards the tradition of burning solid biomass, especially at the household level for cooking. Less than 3% of the population has access to electricity, and even fewer can afford to use it for cooking because it is costly (Taulo *et al.*, 2015; Government of Malawi, 2018a). Paraffin was a popular option for cooking before

removing subsidies in the 1980s (UNDP/Malawi, 2007). On-going rural electrification programme activities have attempted to connect more remote areas in districts to the grid, especially trading and rural growth centres (Malawi Government, 2011; Government of Malawi, 2012a; Government of Malawi, 2018b). The removal of subsidies and increased tariffs to counteract inflationary pressures (Government of Malawi, 2013; Government of Malawi, 2019) suggest that electricity consumption is likely limited to lighting and other less energy-consuming appliances (Jumbe & Angelsen, 2011).

Consequently, charcoal use has been on the increase, especially in urban areas. However, most of the population still rely on burning solid biomass for their energy needs (97%) (NSO, 2012). The use of alternative renewable energy sources in the energy mix has generally been low, mainly concentrated on the transport sector confined to ethanol-petrol blending (Jumbe *et al.*, 2009).

The Government of Malawi recognises the pressure this trend puts on its natural resources. It is reported that over 40% of the forest cover was lost between 1972 and 1990 (Mauambeta *et al.*, 2010). Despite agriculture expansion being cited as an essential contributor to this trend, solid biomass has also added weight to this alarming and increasing trend. Charcoal burning is a vital livelihood strategy, and its growing demand in urban areas fuels its continued existence. The forestry department policy bans charcoal making and selling. However, Mauambeta *et al.* (2010) reported that the production and sale of charcoal were on the increase to the extent that trading happens by the roadsides in full view of authorities. The World Health Organization (WHO) ranked Malawi's national disease burden attributable to Indoor Air Pollution (IAP) (5.2%), from burning solid biomass for energy, as the highest in the region (UNDP/Malawi, 2007). Previous efforts like Programmes for Biomass Energy Conservation (ProBEC), which ended in 2010, promoted efficient rocket stoves for household use and tobacco curing. Women's groups were also trained to produce them as income-generating activities (Malawi Government, 2011). The use of Gel-fuel from bioethanol, an alternative renewable energy source for home cooking (between 2002 to 2005), was discontinued when the manufacturer shut down because rising costs and changes in taxation rendered the business uneconomical (UNDP/Malawi, 2007).

Meanwhile, using ethanol in liquid fuels is a success story that has earned global recognition (Johnson & Silveira, 2014; Nyambane *et al.*, 2020). The history of biofuels in Malawi can be

traced back to 1980, following the 1977 energy crisis (ETHCO, 2019), while the country was still under one-party rule. The one-party structure made it possible to swiftly translate energy security concerns into a bioethanol programme (Johnson & Silveira, 2014). The Ethanol Company of Malawi (ETHCO), a Malawian owned company, was commissioned in 1982 to produce bioethanol from molasses in Nkhotakota District at Dwangwa (central region) (ETHCO, 2020). Excess capacity at ETHCO (as high as 40%) prompted the company to source additional molasses 500 kilometres away using trucks from the Nchalo sugar factory in Chikhawa (Johnson & Silveira, 2014).

The company upgraded its facilities in 2008/09 to the modern molecular sieve dehydration technology, which is superior to the older azeotropic distillation equipment. ETHCO sources its molasses from two local (Illovo-Dwangwa and Samila sugar company) and one internal supplier (Illovo-Nakambala, Zambia) (ETHCO, 2019). The country's second bioethanol production plant was commissioned in 2004 by PressCane Ltd near the Illovo's Nchalo sugar estate, solving the sugar factory's effluent (molasses) disposal problem. The new plant also uses modern molecular sieve technology for dehydration (PressCane, 2020). While the new technology commands higher initial capital outlays, it also paves the way for the company to produce high-grade potable ethanol likely to improve profit prospects. The country's total annual bioethanol processing capacity increased to 30 million litres between ETHCO and PressCane (Johnson & Silveira, 2014).

Malawi's experience with biodiesel is relatively new and mainly associated with one company (BERL). BERL is a private company linked to Dutch TNT, which promoted *Jatropha curcas* hedgerow cultivation around farmers' fields. The company provided smallholders with incentives through its network of extension officers. Planting started around 2008-2009, and the first harvest was around December 2012. Yields from the *Jatropha curcas* trees ranged widely (0.07- 0.4 kgs/tree) because of wild germplasm (von Maltitz *et al.*, 2014; von Maltitz *et al.*, 2016). *Jatropha curcas* trees start to produce seed from the second year of planting and can be productive for 30-50 years. Long-term *Jatropha* yields data is not readily available because systematic monitoring only started recently. Literature suggests that *Jatropha curcas* yields vary considerably in the first two years (0.6 - 4 tonnes ha⁻¹ year⁻¹) depending on soil, climate, and management. There is still uncertainty in the exact yields for *Jatropha curcas* seeds. In semi-arid wastelands, yields can range from 2 to 3 tonnes ha⁻¹ year⁻¹. Other estimates suggest that yields from *Jatropha curcas* trees continue to increase as the trees mature (around

7 years) (van Eijck *et al.*, 2012). The Ministry of Trade and Industry, in collaboration with the Department of Energy, facilitated the operationalisation of BERL's US\$8 million biodiesel processing plant situated in Lilongwe in 2002. *Jatropha curcas* is the primary feedstock for biodiesel production, with a potential capacity of processing 22 million litres annually (Government of Malawi, 2013).

The Malawian government has supported biodiesel development by facilitating the formulation of biodiesel standards. However, as discussed in section 2.3.2, biodiesel production is yet to pick up to make a sizeable contribution to the energy mix in the backdrop of low *Jatropha curcas* yields (Figure 3) (Government of Malawi, 2012a; Malawi Bureau of Standards (MBS), 2012). Malawi imported close to 209 million litres of petrol in 2018 (Government of Malawi, 2019). An E10 ethanol blend can theoretically save foreign currency from export earnings to the value of 20 million litres annually. Gains in foreign currency savings coupled with the company's remittances in taxes underscore the importance of ethanol production for a smaller economy like Malawi (Liwimbi, 2006).

2.3.4 The food versus fuel debate

Increasing biofuels production also comes with the potential threat to food security (Senauer, 2008; Harrison, 2009; Headey & Fan, 2010), igniting the contentious debate on 'food versus fuel'. The discussion generated many informative articles, like the "Biofuels challenge: filling the tank without emptying the stomach" (Rajagopal *et al.*, 2007), "food and fuel for all: realistic or foolish" (Cassman & Liska, 2007), "deal or no deal: the outlook for agricultural land investments in Africa" (Cotula & Vermeulen, 2009) and many more. Agro-fuels directly compete with traditional crops for productive resources and indirectly impact food access through increased food price inflation associated with their increased demand (Chakauya *et al.*, 2009; Molony & Smith, 2010). The direct link is the diversion of tradable market volumes (like USA corn diverted to biofuels) and substituting traditional crops with biofuel crops (Senauer, 2008). When the incentives are conducive, the potential substitution of conventional crops cannot be ignored (Mponela *et al.*, 2011). Smallholder farmers respond to favourable opportunities and prices in making their production decisions (World Bank, 2010). For example, Malawi's 2011 tobacco output fell from 237 million kilograms to just about 80 million kilograms following the previous season's low prices at the auction floors. Consequently, farmers opted to substitute tobacco with alternative crops like cotton

(Government of Malawi, 2012a). Land alienation from conventional crops for biofuels cannot be ruled out when the price is right for smallholder farmers, just like seasonal variations in tobacco prices directly impact the quantities supplied (Mponela *et al.*, 2011; Government of Malawi, 2013).

A World Bank policy brief suggested that the 2006-2008 world food price spike was attributed to various factors, escalated by policy mandate-driven increased biofuels production in the EU and USA (Mitchel, 2008). However, a later study by the World Bank subtly acknowledged that the previous report (policy brief) might have overestimated the contribution of biofuels. Index fund activity (speculative trade activity) played a key role, while biofuels contribution was much less than previously thought (Baffes & Haniotis, 2010). The finding was collaborated by another independent study by the OECD (von Lampe, 2008). Notwithstanding the aforementioned potential threats, agriculture has historically continuously evolved to provide food, fodder, fibre and fuel (4Fs) (Pingali *et al.*, 2008). Biofuels are already part of an integrated agricultural system. The ‘food versus fuel’ problematic argument will not go away (Molony & Smith, 2010). Perhaps what would be helpful is to advance from the dichotomy of ‘good or bad’ into how increased use of agro-fuels can be profitably and sustainably integrated with agriculture (Tomei & Helliwell, 2016). National policies and guidelines on biofuels development need to be redesigned to foster a ‘win-win’ situation for the food and energy security agendas (Subramaniam *et al.*, 2019) to ensure sustainable coexistence (Solomon, 2010; Cheteni, 2017). Generally, the developing world has not benefited much from previous agricultural-led economic growth because of technology adoption and agricultural productivity constraints. Addressing these constraints will be crucial to advance biofuels programmes in developing countries. Applying science to address current limitations can help produce more food and fuel (Kline *et al.*, 2017). Research and development (R&D) is also a possible factor in curbing the competition between food and fuel needs (Lam *et al.*, 2009). R&D can potentially contribute to growing agricultural productivity and explore new products (e.g., second-generation biofuels) (Pingali *et al.*, 2008; Subramaniam *et al.*, 2019). Another important dimension is understanding the ‘populations at risk’ and their local context; biofuels programmes designed to target the rural poor to exploit opportunities and address constraints sustainably can improve food security (Kline *et al.*, 2017). More robust and well-thought regulations are required to make biofuels truly pro-poor (Molony & Smith, 2010). Biofuel programmes which offer ‘diversified and integrated systems that provide clean, affordable

fuels, and nutritious food, increase adaptability and resilience of populations at risk (Kline *et al.*, 2017:573).

2.3.5 Drivers of global biofuels production

According to Chakauya *et al.* (2009), biofuel drivers can roughly be grouped into economic, geopolitical, and technological factors. Economic factors include prices of crude oil, government incentives (taxes, subsidies, *etc.*) and the rural development agenda. Geopolitical factors include energy supply security and environmental issues (such as the 2015 Paris Climate Change Agreements). Lastly, technological factors encompass the availability and advancement of technical options to address constraints to increasing the efficiency of current systems of biofuel generation.

Volatile and increasing crude oil prices led countries to invest in alternative biofuels (Tyner & Taheripour, 2008; Harrison, 2009; Marzoughi & Kennedy, 2012; HLPE, 2013a). For example, the 1977 energy crisis led to establishing the Malawi bioethanol programme (ETHCO, 2019; ETHCO, 2020; PressCane, 2020). In 2007, a combination of factors (including high crude oil prices and diversion of corn from food and feed into bioethanol production in the USA) contributed to supply gaps on the global market, which increased commodity prices (Headey & Fan, 2010; HLPE, 2011). Furthermore, high crude oil prices may improve the economic viability of biofuels, and consequently, refineries increase their margins, thereby creating more demand (Harrison, 2009).

Blending mandates and targets create demand for biofuels (Hayes *et al.*, 2009; Al-Riffai *et al.*, 2010; Taheripour *et al.*, 2010; Sparks & Ortmann, 2011; Taheripour *et al.*, 2011; Timilsina *et al.*, 2011; Gustafson, 2012). The Renewable Fuels Standard of the 2007 US Energy Security Act (P.L. 110-140, H.R.6) targets 36 billion gallons by 2022, with corn providing 15 billion gallons and the remainder from conventional sources (Congressional Research Service, 2007a). Similar policy instruments in the EU (EC/2003/30), South Africa (Renewable Energy White Paper), Ethiopia (Biofuel Development and Utilization Strategy) and Malawi (Energy Policy) have presented arguments for more demand for biofuels (Republic of Malawi, 2003; Department of Minerals and Energy (DME), 2007; Al-Riffai *et al.*, 2010; Lashitew, 2011). Tokgoz *et al.* (2008) estimate that current US mandates will lead to a 55% increase in ethanol

production and an additional 11% increase in acreage. The increase in corn acreage will be compensated by a 6% decline in soybean and wheat planted areas in the USA.

Non-tariff barriers (NTB) such as ‘anti-dumping’ laws, previously imposed on biodiesel imports from the USA to the EU, opened export opportunities for Argentina. Argentina’s soy biodiesel landed costs were significantly lower than production costs in some member states (Spain and Portugal) (Naylor & Higgins, 2017). Similarly, the US anti-dumping duties against biodiesel from Argentina and Indonesia boosted domestic production to a record annual increase of 14% (2.6 billion litres) in 2018 (REN21, 2019). Notwithstanding the EU’s WTO obligations to ensure that non-tariff barriers do not hinder trade, high costs and stringent requirements in RED II exclude African countries from accessing the EU market. A recent CGE study on the impact of RED II NTB in Malawi suggests that there are forgone rural development (1.2% poverty reduction) and economy-wide (1.2% GDP growth) benefits for the smallholder sugarcane out-grower scheme (Schuenemann & Kerr, 2019).

State support through direct and indirect subsidies, taxes (breaks, waivers) and tariffs designed to protect infant biofuel industries, increase their viability and stimulate growth and development (Meyer *et al.*, 2008; Bell *et al.*, 2011; Janda *et al.*, 2011). Various tailor-made government instruments supported the growth of Brazil’s biofuels industry for over 30 years (BNDES Communication Department, 2008). Sparks *et al.* (2011) indicated that an implicit subsidy of R4.37 litre⁻¹ was necessary to bring soybean into feasible economic production of biodiesel on commercial farms in Kwa-Zulu Natal, South Africa. The Malawi government was also instrumental in establishing, developing, and sustaining the performance of a successful bioethanol programme in the SADC region (Johnson & Silveira, 2014).

Increasing awareness of climate change and the 2015 Paris Climate Change agreements motivated the EU to reduce GHG emissions by using alternative biofuels (Dallemand & Vignali, 2008; Chakauya *et al.*, 2009; Gustafson, 2012; European Commission, 2019). The removal of harmful octane³ enhancers (tetraethyl lead & Methyl Tertiary Butyl Ester⁴) due to

¹ Octane refers to characteristics which give gasoline its stability from radical atoms which sometimes result in “knock on” effect on the engine and pre-ignition problems (Thomas & Kwong, 2001).

⁴ MTBE is very soluble in water and there has been evidence of its presence in ground water supplies and posed a potential threat to public health. This led to its subsequent removal as an octane in many countries, including the US (Marzoughi & Kennedy, 2012).

public health threats has also created a demand for biofuels (Thomas & Kwong, 2001). Ethanol is the preferred alternative oxygenator though it displaces petrol in any blend and has less burning power. It is preferred for its renewable sources compared to the alternatives (Cassman & Liska, 2007).

Lauder (2001), cited in Marzoughi and Kennedy (2012), noted that geopolitical factors like instability in the Middle East, which can disrupt crude oil supply and stifle economic growth, made the US government incur over \$35 billion in defence expenditures in 2001 for the region. Although only a small portion can be replaced in fossil fuel with biofuels for high energy-consuming economies, the savings on crude import bills for smaller economies like Malawi can be remarkable (Thomas & Kwong, 2001; Jumbe *et al.*, 2009; Mulugetta, 2009).

Future drivers of biofuels hinge on moving away from first-generation⁵ biofuels. The developments in second-generation⁶ biofuels will rely on the dividends from biofuels research in genetic and chemical engineering (Elobeid & Hart, 2007; Asha *et al.*, 2011). Cellulosic ethanol from lignocellulose and biodiesel from algae are reported to have good potential (Cassman & Liska, 2007; Hochman *et al.*, 2008), which suggests that a niche exists for the development of public-private partnerships (PPP) (Cassman & Liska, 2007; McLaren, 2008). A further innovation is required to overcome current hurdles related to plant science (increasing productivity and scalability), technology (processing and handling), and the legislative and legal framework of promising options. Scepticism on genetic and chemical engineering to produce exponential yield growth stems from a lack of scientific evidence (Cassman & Liska, 2007).

2.3.6 Biofuels and the environment

Reduction in GHG emissions (to which agriculture is the major contributor) (HLPE, 2012a) is a compelling attribute supporting biofuels development. Janda *et al.* (2011) reviewed several

⁵ First generation biofuels are produced from traditional food and vegetable oil crops with significant amounts of starch, sugars and oil (examples include: corn, wheat, sugarcane, sugar beet, soybean, palm oil) (BNDES Communication Department, 2008).

⁶ Second generation biofuels production relies on various chemical processes to produce cellulosic ethanol from sources like perennial grasses (switchgrass, Miscanthus, agricultural waste) and biodiesel from jatropha and potentially from microalgae. However, this technology has not matured yet for scaling up (Solomon, 2010; Asha *et al.*, 2011).

studies that used life cycle assessment (LCA) to determine the contribution of various feedstocks to GHG emission reduction. Essential characteristics that improve crops' contribution to GHG emission reduction were high yields, the possibility/ability to use crop wastes, and the value of co-products. Additionally, increasing the productivity of current known feedstocks is arguably the best strategy to boost a crop's standing on the hierarchy of their contribution to GHG emission reduction.

Biofuels have also been known to cause land-use change which has several consequences (Timilsina *et al.*, 2010). Loss of biodiversity, disruption of carbon sinks, up-front GHG emissions, and replacement of more efficient carbon sequesters have been reported (Searchinger *et al.*, 2008; Fargione *et al.*, 2010). The land-use changes associated with *Jatropha curcas* cultivation will mainly depend on the adopted mode of production. The actual biodiversity impacts are not well-known; however, where *Jatropha curcas* plantations replace existing forests or grassland, significant potential losses are likely (Gasparatos *et al.*, 2012).

A lively debate ensued from the various commonly used GHG emission LCA methods, amidst concerns of improper accounting for land-use change, water use, indirect land-use change, and carbon costs (Achten *et al.*, 2008; Searchinger *et al.*, 2008; OPEC, 2009; Fargione *et al.*, 2010; Lora *et al.*, 2011). The most important criticism was by Searchinger *et al.* (2008). They suggested that the growing of conventional food crops prevents GHG emissions from land-use change, which is a corollary benefit to the environment. Earlier assertions that corn contributes up to 20% GHG saving, a default variable in the GREET⁷ model, are challenged when land-use change is considered (Hill *et al.*, 2006; Searchinger *et al.*, 2008). When land-use change is accounted for, their estimates indicate corn-ethanol causes a negative 40 % carbon debt, almost twice earlier reported figures in GHG saving (20%), which will require a 167 year repayment period. Fargione *et al.* (2010) make similar claims; they highlight the inconsistencies in accounting for land-use change leading to illegitimate assertions on GHG savings. Sugarcane remains a superior feedstock when it comes to net beneficial GHG emissions, far exceeding grain-based ethanol (Al-Riffai *et al.*, 2010; Doku & Di Falco, 2012).

⁷ Greenhouse gases, Regulated Emissions and Energy use in Transport (GREET) is anchored by the US Department of Energy's Office of Energy Efficiency and Renewable Energy. The GREET model is used to assess energy and impact data from cradle-to-grave using LCA of fuels used in transport (Searchinger *et al.*, 2008).

Nonetheless, Kline and Dale (2008) strongly disagree with the views expressed by Fargione *et al.* (2010) and Searchinger *et al.* (2008). They fault their outputs as marred by the narrow causal effect of land-use change caused by the conversion of grassland and forest into agriculture. They suggest that the interaction of various factors like demographic, biophysical, cultural, technological, and political in space and time are the main parameters driving land-use change.

Senauer (2008) highlights the problems with converting fragile ecosystems like marginal lands and peatlands in Malaysia and Indonesia for palm oil production, especially since the latter accounts for up to 47% of the world's peatlands. Further emphasis has also been placed on proper accounting for nitrogen dioxide (NO₂) emissions from peat soil when land is converted for biofuels production (Bell *et al.*, 2011; Reinhardt & von Falkenstein, 2011).

The above claims are also relevant to SSA considering that marginal lands are the prime targets for biofuels production in many countries like Botswana, Ghana, Nigeria and Ethiopia (Kgathi *et al.*; Lashitew, 2011; Wicke *et al.*, 2011; Abila, 2012; Kgathi *et al.*, 2012; Ahmed *et al.*, 2017). Nevertheless, key questions linger around what constitutes, and who is defining the 'degraded', 'marginal', 'underutilised', or 'idle land', and from 'whose lens', remains a contentious issue (Chinsinga, 2008a; Chasukwa, 2013; Chinsinga *et al.*, 2013).

A recent study compared carbon savings from *Jatropha curcas* hedge-rows and plantations in Malawi and Mozambique. The results suggest that plantations returned a carbon debt while hedge-rows had positive net balances. Previous land use was a crucial factor in the negative impacts of *Jatropha curcas* plantations in Mozambique, where a high-density forest was converted to *Jatropha curcas*. Conversely, a land-use change resulting from hedge-rows planted on field boundaries banked net positive carbon dioxide returns in Malawi (BERL sites) (Romeu-Dalmau *et al.*, 2016).

The ecosystem services (grazing, hunting, regeneration etc.) derived from communal land used by the poor are arguably not correctly accounted, commoditised, or not evident enough to get 'imputed values' in reforms and land suitability assessment (Chambers, 1995; Barnett *et al.*, 2008; Ambali *et al.*, 2011; Wicke *et al.*, 2011). These arguments call for proper accounting of other sources of livelihoods. Land management reforms, classification, and suitability assessments need a multi-disciplinary approach, including civil society participation, before

embarking on development programmes (such as sugarcane, biofuels promotion, etc.) (Molony & Smith, 2010; HLPE, 2013b).

2.3.7 Biofuels, food security and rural livelihoods

Apart from curbing GHG emissions, and savings on crude oil import bills, biofuels can improve rural livelihoods through economic integration of rural people through employment and out-grower schemes (Amigun *et al.*, 2008; von Lampe, 2008; Ambali *et al.*, 2011). However, mere optimism without careful consideration of costs and “trade-offs” can be detrimental. Concerns of ‘land-grabbing’ and ‘re-colonisation’ discussed in section 2.31 through the expropriation of land need to be examined diligently (Molony & Smith, 2010; Havnevik, 2011; Chasukwa, 2013). However, proper management of negotiations and careful selection of business models in an inclusive manner with civil society can avoid such cases. The inappropriate issuing of long-term land contracts led to political instability in as was the case in Madagascar, threaten land tenure security (Cotula & Vermeulen, 2009).

Achten *et al.* (2010) suggest that small-scale community-based initiatives involving *J. curcas* production minimise risks associated with large scale plantations and are lenient on the ecosystem. These initiatives also provide additional livelihood options for smallholders. Furthermore, Dyer *et al.* (2012) argue in their response to Achten *et al.* (2010) that in Malawi, *J. curcas* production has the potential to improve rural household expenditures and generate additional incomes through seed sales and value addition activities (paraffin extraction and soap).

Food crop production is an essential livelihood strategy for household food self-sufficiency and income generation in Malawi (Kamanga *et al.*, 2009; Dyer *et al.*, 2012; Mapila *et al.*, 2012a). For communities near forest reserves, forest resources provide important livelihood incomes, especially for the low to the middle-income category. Any physical loss of forests (conversion to agricultural production) and access to their resources poses a threat to livelihoods (Kamanga *et al.*, 2009). Growing energy crops for biofuels production is likely to alter conventional cropping patterns and impact on livelihood assets such as land, natural forests, and water. The changes may lead to the ‘systematic’ re-purposing of land use from producing conventional food crops to others (such as energy crops). Other quarters have

suggested that “the current wave of contract farming and outgrowing initiatives, border on the altering of land uses - or ‘systematic’ land grabbing” (Chasukwa, 2013:15).

The expected benefits from job creation and wage employment (Panoutsou, 2007; Mwakaje, 2012) is seen as an equalising factor for well resource endowed areas that can support biofuels development to those with limited capacity (Pingali *et al.*, 2008). Production of feedstocks is a rural-based activity, and it may have positive contributions to resource-poor farmers and improve rural incomes (Solomon, 2010). Other benefits such as the supply of energy to remote areas, potential health benefits to rural women from cooking using cleaner alternative fuels, increased rural incomes, and technology spill-overs have been mentioned (Panoutsou, 2007; Pingali *et al.*, 2008; Ewing & Msangi, 2009; Arndt *et al.*, 2010; Solomon, 2010; Bouffaron *et al.*, 2012).

Lessons from India suggest that thorough appraisals are necessary to avoid negative impacts on existing livelihood strategies (Findlater & Kandlikar, 2011). A livelihood lens can be instrumental in ascertaining the sustainability of these interventions and reducing externalities (Murambadoro, 2009).

Land expropriation, usually under non-transparent policies, little documentation of negotiations and limited compensation for *J. curcas* production, brought undesired problems in Ghana (Ahmed *et al.*, 2017). The loss of livelihoods quality through increased food insecurity, reduced incomes and forgone access to vital forest products has been documented. Such improper conduct, which often flourishes with limited knowledge of government and affected households, accentuate the need for more robust systems and regulatory frameworks that can protect rural communities' values (Schoneveld *et al.*, 2010 cited in Jumbe & Mkondiwa, 2012).

2.4 Summary

This chapter reviewed important global and domestic trends in biofuels production and highlighted the interface between biofuels, livelihoods, and the environment. While global biofuels production data display the world outlook on the performance of the major players in the industry, Malawi's domestic production trend brings a perspective of a smaller economy.

Some emerging issues from these trends were also discussed. The review also focuses on the synopsis of the bioenergy outlook in Malawi.

Overall, global trends indicate that biofuels production has increased by 53% for bioethanol and 169% for biodiesel over the last decade alone (REN21, 2019). Prospects are high that current production levels are likely to remain stable in the medium term with sustained and renewed mandates on the global (USA and EU) and local (Malawi) markets (Government of Malawi, 2018b; European Commission, 2019; REN21, 2019). Corn remains the most important feedstock for US bioethanol, while sugarcane is the primary feedstock for bioethanol in Brazil. Various other feedstocks are used for biodiesel production in different regions, including rapeseed (EU), palm oil (Malaysia and Indonesia), and *Jatropha curcas* (Africa and Asia) by the world's major biofuel producers. The USA (20%), Brazil (12%), and the EU (17%) are the leading biodiesel producers contributing nearly half (49%) of the global output. Africa's contribution at the international stage still lags major producing regions despite being claimed as an area with great potential for bioethanol and biodiesel production. Malawi stands out as a global success story on public-private partnership in biofuels development. Malawi is a small developing country that did not wait for foreign intervention to launch its biofuels programme (Johnson & Silveira, 2014). Biodiesel production, led by yet another private company (BERL), has not, however, gained momentum amidst low *Jatropha curcas* yields (Schuenemann & Kerr, 2019). BERL first announced plans to start commercial production in the 2013 season with a capacity of 750,000 litres per year (Government of Malawi, 2013).

Chapter 3: A rural household typology, characterisation of smallholders, and *Jatropha curcas* feedstock producers in southern Malawi: constraints and opportunities for improving livelihoods⁸

3.1 Introduction

The integration of smallholders in the biofuels value chain in southern Africa seems to be driven more by the rural development hypothesis as compared to energy security and climate change objectives (von Maltitz *et al.*, 2018). Land tenure security concerns raised by stakeholders due to biofuels promotion, coined ‘land grabs’ by others (Matondi *et al.*, 2011), suggest that the out-grower biofuel business model is likely to be a more plausible option for the smallholders compared to plantations (von Maltitz & Setzkorn, 2013). The out-grower business model enlists the smallholders as landowners to produce feedstocks on their land (German *et al.*, 2011). Smallholders in Malawi in some districts grow *jatropha curcas* as a complimentary high-value tree crop for biofuels production (Makungwa *et al.*, 2013; Wiyo & Banda, 2014). These smallholders have diversified into growing energy crops from traditional crops (such as cereals, legumes, roots and tubers) in a predominantly food-cash crop agricultural system (Government of Malawi, 2013).

The smallholder agriculture sector plays an essential role in the livelihoods of rural masses, who are mostly rural dwellers (84%) in Malawi (National Statistical Office (NSO), 2018). Given the vital role and size of the smallholder agricultural sector, as is the case in most developing countries, the industry policies have significant implications for the countries’ social and economic paths (Lora *et al.*, 2011; Fan *et al.*, 2013).

Like most countries in southern Africa, the smallholder sector is affected by a myriad of challenges, which range from natural shocks (weather-related) to human-made shocks (market failures, price volatility, etc.) (World Bank, 2007). The variations in agroecological terrains, weather conditions, edaphic factors, and the socioeconomic environment inform smallholder livelihood strategies and trajectories. The development domain dimensions (agro-ecological

⁸ This chapter is based on the following paper: Chamdimba, O.Y., Ortmann, G.F. & Wale, E. A rural household typology, characterisation of smallholders, and *Jatropha curcas* feedstock producers in southern Malawi: constraints and opportunities for improving livelihoods. Submitted to *Land Use Policy*, under review.

potential, market access, and population density) concept has been used to analyse the constraints and opportunities for agricultural production investments (Pender *et al.*, 2004; Kruseman *et al.*, 2006). Agroecological potential (moisture-rainfall, soil and temperature) has been used in the geographical demarcation of absolute agricultural potential in various areas, including Malawi (Chamberlin *et al.*, 2006; Chinsinga, 2008b). Market access (distance to outlets, infrastructure, ICTs) turns absolute potential into a comparative advantage, separating two similar locations (Chamberlin & Jayne, 2013). Population density is the demographic dividend that relates to the comparative labour advantage and demand for goods and services (Pender *et al.*, 2004). However, development domains are best suited as first-order filters to identify broader constraints and opportunities for rural development. Lower level-specific interventions require going beyond development domains to identify the specific interventions, commodities or technologies for livelihood improvement (Pender *et al.*, 2004).

Agricultural systems research describes a farming system as the totality of all the household's unique production and consumption decisions. Smallholders differ in resource endowment, composition, decision making, and farming experiences, a construct that is not necessarily static but continuously evolving (Köbrich *et al.*, 2003; Tittone *et al.*, 2010). Thus, smallholders' diversity entails that they are not affected in the same way by constraints in their pursuit to undertake potentially profitable activities in the agricultural sector (Fan *et al.*, 2013). This diversity also calls for diverse development policy interventions (Snapp *et al.*, 2003; Kamau *et al.*, 2018; Makate *et al.*, 2018a; Cele & Wale, 2020).

A practical way of addressing the heterogeneity in smallholders' farming systems is to classify or group homogenous households into clusters based on their similarities (such as resource endowment, enterprise choice, experience, etc.). The various typologies reflect the striking resemblance (within each cluster) and dissimilarities (between the groups) in the characteristics of smallholders (Kuivanen *et al.*, 2016a). Qualitative methods use tools such as Participatory Rural Appraisal (PRA) or Rapid Rural Appraisal (RRA) to create typologies aimed at logically stratifying households into groups based on subjective measures or perceptions (e.g., wealth ranking) (Bond *et al.*, 2007; Kamanga, 2011). However, the limitations of participatory approaches rest in the subjectivity of the assessments. Conversely, quantitative methods employ multivariate techniques which use salient homogenous features to group smallholders into distinct clusters as applied in various settings and studies (Köbrich *et al.*, 2003; Hair *et al.*, 2014; Kuivanen *et al.*, 2016a). Kuivanen *et al.* (2016a) suggested a more flexible method

that combines qualitative and quantitative measures, an approach adopted in this study (Kumar *et al.*, 2019). The choice of variables used in typology development is extensive and diverse for different studies depending on the objectives, including farm-specific, demographic and other socioeconomic characteristics (Chikowo *et al.*, 2014; Hazell & Rahman, 2014; Kamau *et al.*, 2018). The results from the classification of smallholders can streamline the targeting of beneficiaries, interventions, and monitoring the investments (scaling up of impact assessments) (Chikowo *et al.*, 2014; Jones *et al.*, 2014; Kuivanen *et al.*, 2016a).

The purpose for creating typologies and researchers' knowledge are important tenets that guide the development process. There are many different ways on how to build typologies in the literature. For example, AGRA (2017) used a proportion of non-farm income and production put to sale to classify smallholders into four typologies based on commercialisation stages. Several studies in sub-Saharan Africa have employed the typology approach in agricultural systems research to study heterogeneity among smallholders, as summarised by Chikowo *et al.* (2014).

Tittonell *et al.* (2010) used a functional approach to analyse the diversity's influence on soil fertility status and spatial variability. The study categorised smallholders into five distinct typologies based on soil fertility status. Soil carbon and nutrients were important factors explaining the variation in soil fertility across the typologies. The study showed that soil spatial variations increased with the number of livestock owned. The different smallholder typologies would require targeting with specific technological interventions to improve soil quality. The empirical evidence suggests that livestock manure was an important element in improving soil quality. The findings also suggest that development programmes that include livestock rearing promotion may yield multiple benefits (soil fertility inclusive).

Typologies have also been used to analyse patterns of use of agricultural innovation and smallholder practices. A recent study in Rwanda used typologies to analysed diversity in smallholders' use of new technologies. Smallholders were categorised into five typologies. Gender of the household was a dominant feature in the choice of sustainable agricultural practices. An intervention's associated costs seemed to be the critical factor demonstrated by the uptake of relatively cheaper options (compost and green manure) by female-headed households. Farming experience was inversely related to the update of innovations (fertiliser use) which reaffirms the vital role of smallholders' risk perceptions and attitudes in the

adoption process. The importance of education in innovations adoption was consistent with other studies on its role in innovation diffusion (Marra *et al.*, 2003; Bidogeza *et al.*, 2009).

Makate *et al.* (2018a), using data from three countries, Zimbabwe and the Chinyanga Triangle (CT) Area (Mozambique, Zambia and Malawi), applied typologies to analyse smallholders' diversity in the adoption of climate-smart agriculture technologies. The study identified six clusters for the Zimbabwe and CT sample. The results suggest that female-headed households were among the low adopters of climate-smart agriculture interventions, which was inconsistent with another related study in Rwanda on similar technologies (Bidogeza *et al.*, 2009). Wealthier smallholders were better adopters of climate-smart technologies as compared to poor subsistence farmers. This finding was consistent with another study done in India (Lopez-Ridaura *et al.*, 2018). Despite being full-time farmers, the smallholders who did not perceive farming as their primary source of income were also low adopters. The results suggest that poor smallholders had access to off-farm income that contributed more to their households than farming. The study also highlighted the importance of land tenure security to increase climate-smart agriculture technologies' uptake, consistent with a recent study in Ethiopia (Mutyasira, 2020).

Another study on the intensification of sustainable agriculture practices in Ethiopia categorised smallholders into four clusters. The empirical findings suggest that sustainable intensification strategies will require improving the smallholders' financial and human capitals (off-farm incomes, credit, agricultural training and technical services). Increasing access of smallholders to productive land and addressing land tenure security concerns were also important factors increasing agricultural intensification strategies. Secure land tenure can encourage investments in long-term technologies like agroforestry and land management practices (soil and water conservation), requiring relatively more extended periods to show benefits (Mutyasira, 2020).

Kamau *et al.* (2018) applied typologies to analyse smallholders' diversity in organic and conventional farming practices in Kenya. The study identified five typologies and highlighted the importance of social networks in accessing high-value markets. Farming experience was an important factor in accessing opportunities in the organic markets. Legal ownership of land was a critical factor for participation in organic markets, suggesting that land tenure insecurity was a barrier to entering high-value agriculture markets. Smallholders with higher access to information were also likely to participate in organic agriculture. Access to information on

services (markets, prices) and more robust social networks had better chances of exploiting opportunities in the lucrative organic markets.

Dunjana *et al.* (2018) identified three typologies of smallholders in the food-cash crop production systems from the resettlement area in Zimbabwe. Labour constraint was reported as a significant constraint to improving production. Various typologies also differed in their ownership of agricultural equipment, which has implications for land utilisation and production levels. The results suggest that where land is not a limiting factor, the other production constraints need to be considered to increase production.

A literature review on similar efforts to characterise smallholders in Malawi engaged in predominantly food-cash crop production systems showed that some studies used typologies in various fields of agricultural systems research. Orr and Jere (1999) used typologies to classify smallholders into five groups to evaluate appropriate integrated pest management strategies for each cluster in southern Malawi. Kamanga (2011) applied the typology approach to study soil fertility management, which identified three farmer typologies based on resource endowments in the central region of Malawi. Another study in the central region used typologies to stratify smallholders in the maize mixed farming system under semi-arid zones. The study classified smallholders into three homogenous groups to target technologies (Mponela, 2016). A recent study used farm typologies to study farming systems diversity and its relative importance for farm efficiency in central and southern regions. The study classified smallholders into two clusters: land-constrained maize-based smallholders and diversified crop-livestock producers (Berre *et al.*, 2017). von Maltitz and Setzkorn (2013) also evaluated a typology of the feedstocks in biofuel projects in the southern Africa region, including Malawi. The study described, among others, types of feedstocks and the smallholder out-grower business model arrangement where smallholders received technical support and supply biofuels companies with feedstock.

No study in Malawi applied typologies to analyse the heterogeneity among smallholders, energy crop producers and compare them in a food-cash crop production system to the author's best knowledge. This study combined qualitative and quantitative variables, an approach suggested by Kuivanen *et al.* (2016a). Furthermore, the study used a different set of variables which included, among others, usufructuary land rights considered pertinent for perennial crops like *Jatropha curcas*. Therefore, the current study's objective was to analyse and compare

farming systems' heterogeneity for smallholders and energy crop producers. The specific objectives were: (i) to identify typologies of smallholders and factors which explain their variability, (ii) to analyse the distribution of *Jatropha curcas* cultivating farmers and non-growers in the identified typologies, and (iii) to identify typology specific constraints and opportunities for targeting of interventions to improve rural livelihoods.

This chapter investigates heterogeneity sources among smallholders and determines typologies, opportunities, and constraints for rural livelihood improvement in a food-cash crop production system. PCA and CA analysis were used to generate typologies of smallholders. ANOVA was applied to characterise the different typologies. The results compare heterogeneity among smallholders and farmers who diversified into the cultivation of energy crops, an area that has received less attention in previous studies. The findings provide policy options based on the smallholders' unique characteristics, focusing on the available opportunities and constraints for rural livelihood improvement.

Regarding the chapter's organisation: Section 3.2 presents the methodology that discusses the empirical strategy used to address the study objectives. Section 3.3 presents the study results and discussion. The last section summarises the chapter, while the study conclusions and recommendations are consolidated in chapter 6.

3.2 Methodology

3.2.1 Description of the study area

The study was conducted in the Mangochi District of southern Malawi (see Figure 4) in July 2014, following a reconnaissance survey. The reconnaissance survey was conducted in April 2014 to confirm the availability of a large sample of smallholders cultivating energy crops. A snowball method involved visiting and holding discussions with various stakeholders in the biofuels value chain, including BERL. The entities visited included the Agriculture Development Division (ADD) office of the Ministry of Agriculture and the relevant Rural Development Programme (RDP) offices at the district level (Dowa, Salima, Nkhotakota, Lilongwe, and Mangochi Districts). The selected study site (Mangochi District) targeted an area where BERL received the bulk of *Jatropha curcas* seeds and the availability of a relatively large sample of *Jatropha curcas* cultivating smallholders. Mangochi District was also one of

the few areas in southern Africa where smallholder out-grower *Jatropha curcas* schemes were still operational (von Maltitz *et al.*, 2016).

The Mangochi District is under the Machinga Agriculture Development Division (ADD) in the Ministry of Agriculture's administrative structure. Mangochi covers 6,729 km² of land located at the southern tip of Lake Malawi with a stretch of water that extends inland (Figure 4) (National Statistical Office (NSO), 2018). The district is located at an altitude of 492 meters above sea level, receives an average of 983mm of rainfall, while temperature ranges from 14.5 to 33.5 degrees Celsius (Katengeza *et al.*, 2012). Mangochi has a rapidly growing population (3.6 % annum⁻¹), increasing by 44% in just a decade to 1.15 million inhabitants in 2018. The age structure showed a very youthful population (60% under 20 years and 75% under 29 years) and had the highest number of economically inactive persons in the southern region (154,464 persons). The gender ratios indicated that there were 90.4 males per 100 females. Mangochi also has the lowest literacy levels (53%) (ability to read and write) in the country (National Statistical Office (NSO), 2018).



Figure 4.0 Map of Malawi showing the selected study district (Mangochi) marked by the green arrow.

Source: nationsonline.org, 1998-2020.

The Mangochi District is part of the southern lakeshore livelihood zone. Rural livelihoods in the Mangochi District depend on agriculture, and major crops include maize, pigeon peas, rice, cotton and tobacco. Minor crops grown are groundnuts, cowpeas, bambara nuts, velvet beans, sorghum, *Jatropha curcas*, and soybeans. The district is also the country's major fishing area

alongside three other lakeshore districts. The fishing industry directly employed 16,000 people, while a further 40,000 benefited indirectly in 2012 from various related economic activities (fish trading, boat making, fishing gear) (ICEIDA, 2012).

3.2.2 Sampling and the data

The data were collected in July 2014. The study used a combination of purposive and random sampling strategies at the different stages of sampling. Following a reconnaissance survey mentioned earlier, agricultural Extension Planning Areas (EPAs⁹) were purposively selected in the BERL investment zones where they promoted *Jatropha curcas* cultivation in Mangochi. Smallholders cultivating *Jatropha curcas* were then randomly selected (treatment sample). The counterfactual households (untreated group) were randomly drawn from similar neighbouring EPAs, where BERL did not promote *Jatropha curcas* cultivation. Four EPAs were selected for the study with the help of the Mangochi District agriculture staff, two for *Jatropha curcas* cultivating farmers (Nankumba and Lingwena EPAs) and two for the non-*Jatropha curcas* growers (Maiwa and M'bwadzulu EPAs).

A structured household questionnaire (Appendix B), which was pre-tested in Cholwe EPA (in Lilongwe ADD), was used to capture information on agricultural practices, outputs, household demographics and socioeconomic information relevant to the study. The key informant and focus group discussion checklists were used to collect additional information to complement the structured questionnaire (Appendix C). Hired enumerators were trained and familiarised with the data collection instruments before administering them. A total sample of 298 farmers was interviewed. The sample comprised 100 *Jatropha curcas* cultivating farmers (hereafter JCFs). For every JCF interviewed, two non-*Jatropha* farmers (hereafter NJFs) were also interviewed to increase the chances for identifying counterfactuals required in some techniques used in the analysis and to manage budgetary and logistical constraints. Qualitative information was also gathered using participatory rural appraisal techniques to complement the household questionnaire. Focus group discussions with the representative of both categories of smallholders (male and female) were conducted. A checklist was used to guide the discussion sessions to collect more information that the structured questionnaire could not easily collect.

⁹ EPAs are the lowest administrative structures in the agriculture extension system of the Ministry of Agriculture in Malawi.

A total of two community focus group discussions were conducted, one for JCFs and another for the NJFs. Lastly, key informant interviews were also conducted with the Agriculture Extension Development Officers to gather general agricultural related information (subsidy, crop estimates, farm families, etc.) about their areas. Four key informant interviews, one with a chiefs counsellor and three with AEDs, were conducted.

3.2.3 Theoretical framework

The typology development process varies based on the theory and its objectives (Emtage *et al.*, 2006; Goswami *et al.*, 2014; Weltin *et al.*, 2017). There is no strict guiding framework for the development of typologies in the literature. The basic tenets are validity, usefulness, and a rich dataset to accord small groups representation in the clusters (Pienaar, 2013; Hair *et al.*, 2014; Kajombo *et al.*, 2014).

This study adopted the sustainable livelihood (SL) framework. The SL framework recognises the household as a decision-making unit in a dynamic environment. The framework contends that smallholders use various assets to create a portfolio of livelihood strategies within the vulnerability context's confines and governing structures to generate the outcomes (Scoones, 2009). Livelihood strategies undertaken by the resource-poor are diverse and often complex, though some may appear small but have significant implications on their livelihood outcomes (Chambers, 1995). Furthermore, these strategies tend to have important explanations of peoples' complex way of life sometimes (Ayele *et al.*, 2010).

The SL is a versatile and widely used research tool in the development field canvassing many years because it can capture a broad spectrum of how people live (Emtage *et al.*, 2006; Bhandari & Grant, 2007; Berchoux *et al.*, 2019). The framework contends that smallholders analyse constraints and exploit opportunities to pursue potentially rewarding ventures for livelihood improvement (Bhandari & Grant, 2007). In this study, smallholder heterogeneity analysis was not limited to known indicators like income or consumption and demographics, but also farm variables, access to services, outcomes like food security, usufructuary rights, and other endowments (Chiwaula & Waibel, 2009).

3.2.4 Empirical strategy

There are several ways used to construct typologies. Participatory approaches use ranking based on defined criteria to segregate units of interest in the generating typologies (Kuivanen *et al.*, 2016b). Multivariate quantitative statistical techniques include multiple correspondence analysis, discriminant analysis, factorial analysis PCA, and Cluster Analysis (CA). PCA and CA are widely used methods in the construction of typologies in rural development research space because they reduce data dimensionality by generating a few new principal components, which retain the largest variations in the original dataset (Jolliffe, 1986; Kuivanen *et al.*, 2016a; Makate *et al.*, 2018a; Mutyasira, 2020).

In this study, PCA was used to reduce the data dimensionality of selected variables from the SL framework's various capitals. PCA generates new principal components representing the original dataset's most significant variations (Jolliffe, 1986; Browne *et al.*, 2014). Cluster analysis groups units based on within-cluster homogeneity and the heterogeneity between the identified groups. PCA and CA have been used in previous studies under various empirical settings (Bidogeza *et al.*, 2009; Chipfupa & Wale, 2018; Dunjana *et al.*, 2018). The PCA procedure is a necessary first step to conduct before cluster analysis to characterise the smallholders. The new uncorrelated principal components generated from PCA were subjected to a two-stage cluster analysis procedure. Before performing the PCA, the data were subjected to Bartlett's sphericity test and Kaizer-Meyer-Olkin (KMO) sampling adequacy to ascertain if it was appropriate for the procedure (Hair *et al.*, 2014; Makate *et al.*, 2018b).

The next step involved subjecting the new principal components from the PCA to a cluster analysis procedure. A hierarchical agglomerative method was used to analyse the smallholders' variations and define the number of typologies (K_i). Ward's technique was the algorithm used which combines any two clusters that minimise the within-cluster sum of squares across the separate groups. Ward's method generates groups that have reasonably balanced representation across clusters. The only major limitation of Ward's approach is that smaller unique clusters are not easily identified. A dendrogram tree gives a graphical representation of this process (Hair *et al.*, 2014). After this process, a non-hierarchical procedure was conducted to refine the K_i typologies. Lastly, a one-way analysis of variance (ANOVA) was conducted to analyse the differentiating variables explaining the typologies' variations. This approach helps identify the

distinguishing factors between the typologies (Chipfupa & Wale, 2018; Makate *et al.*, 2018a). All the analyses were conducted using the built-in commands in STATA-15.

3.2.5 Variables used to construct the typology

The variables used in this study to construct the typologies are presented in Table 3. The selection of the variables covers farm and smallholders' socioeconomic characteristics that describe the households' setup from assets to rural livelihoods outcomes. The demographic characteristics included gender, dependency ratio, household head education level, average household education endowment, farming experience, household members of working-age, and available labour discounted for land availability. Land tenure security was captured as usufruct land rights, calculated as the percentage of land that has relatively secure usufruct land rights (inherited from parents or bought) to total landholdings. Endowment factors included a wealth index and land availability discounted to per adult equivalent¹⁰, ownership of telecommunication equipment was a principal component (Pc) aggregated index (cellphone, radio and television), and total livestock units. Other factors were crop diversity, access to credit, access to extension services, access to off-farm incomes, quantities of fertilisers used, the value of hired labour, perceived level of food production, the value of stored food, the value of livestock sales, value of crop sales and consumption expenditure discounted to adult equivalent units.

Table 3 Variables used in the construction of farmer typologies

Variable	Description and measurement	Means	SD
AGE_HH	Age of household head (years)	45.6	14.8
GENDER	Gender of household head (1=male, 0 female)	0.72	0.45
DEP_RATIO	Dependency ratio (ratio of dependents to adults)	0.49	0.23
ECON_INDEP	Number of household members (15-65 years)	2.98	1.33
EDUC_LVL	Years of education for the household head	5.4	4.27
EDUC_ENDW	Average years of education for all the household members.	4.48	1.83
FARMNG_EXP	Farming experience (years)	27	14.9

¹⁰ Household size adjusted for age and gender (Ligon & Schechter, 2003).

Variable	Description and measurement	Means	SD
LAND_CONSTR	Land holdings per capita in adult equivalent ¹¹ (ha)	0.25	0.24
TENR_SCR	Usufruct land rights ¹² (%)	0.65	0.46
LBR_HA ⁻¹	Labour constraint factor (ratio of domestic labour to land)	4.0	3.37
HIRED_LBR	Value of hired labour used per year ('000 Kwachas)	5.51	17.84
DIVERSITY_INDEX	Crop diversity index ¹³ (count of crop species, i.e., legumes, cereals, tree-crops etc.)	1.94	0.79
FERT_KGS	Inorganic fertilisers used (kgs)	94.7	107.5
TLU	Total livestock units ¹⁴	0.811	3.07
CREDIT_ACC	Access to credit (1=yes, 0 otherwise)	0.25	0.43
EXTN_ACC	Extension access (1=yes, 0 otherwise)	0.70	0.46
ACC2_OFF_FARM\$	Access to off-farm income (1=yes, 0 otherwise)	0.51	0.5
PRODN_LVL	Perceived level of food production (1= enough, 0 otherwise)	0.33	0.28
WEALTH_INDEX	Pc-index for household durable assets	-2.05e 03	1.4
CROP_SALES	Value of crop sales per year ('000 kwachas)	46.6	82.33
LIVSTK_SALES	Value of livestock sales per year ('000 kwachas)	11.7	34.57
INFO_TECH	Pc-index for telecommunication assets (cellphone, radio, television)	1.57e-07	1.22
LN_HHEXP_AEU	Log household expenditure per adult equivalent	10.98	0.58

¹¹ Landholdings adjusted for age and gender of the household members into per adult equivalent units (Ligon & Schechter, 2003).

¹² For the purposes of this study, tenure security was not restricted to formal entitlements but rather encompassed all the informal usufructuary arrangements, which allow inhabitants of land to enjoy utility of the land (Government of Malawi, 2002). The usufructuary land rights was constructed as a percentage of landholding under relatively secure usufructuary (inherited or bought with cash) land to total land under cultivation.

¹³ Crop species index was constructed as a count of number of different species of crops grown.

¹⁴ Tropical livestock units (TLU) is a widely used measure for livestock kept based on body weight regardless of species compared to a 250kgs animal.

Variable	Description and measurement	Means	SD
LN_FOOD-STOCKS	Log of the value of stored food stocks	9.95	2.58

Source: Own Survey, 2014.

The Bartlett Sphericity test was used to assess the suitability of the variables in Table 3 for PCA analysis. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (0.72) was more than 0.5, which is considered adequate as applied in many studies. The Bartlett sphericity test strongly rejected the null hypothesis ($X^2= 1134$; p-value =0.000), indicating sufficient correlation among the variables and, therefore, suitable for performing PCA (Hair *et al.*, 2014).

3.3 The results and discussion

The focus group discussions revealed that most households rely on farming as the primary source of livelihoods complemented by petty trading and some fishing activities. The primary food crops grown are cereals (maize), legumes (beans, pigeon peas) and cash crops (tobacco and cotton), while horticulture crops (vegetables, tomatoes) and energy crops (*Jatropha curcas*) are minor crops. The primary constraints to agriculture production ranked climate variability as the most significant factor, followed by the high price of agricultural inputs, pests and diseases, and security of crops (from theft and animals). Yield variability and low consumption of inorganic fertilisers were reported as the direct consequences of these constraints. Further analysis of farmer typologies refines information on constraints and opportunities and the distribution of smallholders relative to the limitations.

3.3.1 The principal component analysis results

According to Hair *et al.* (2014), PCA analysis can be conducted on a dataset as long as the variables are below thirty. The analysis extracted eight components with eigenvalues greater than 1 out of the original 22 farm and farmer characteristics used to describe the sample (Table 3). A cut-off point for factor loadings equal to or greater than 0.4 was used to define the extracted components. The components together explained 62.3% of the variations in the original dataset, which is above 60% considered generally acceptable in social sciences (Hair *et al.*, 2014).

The first component (Comp1- *land endowment, crop diversity and food reserves*) explained 10% of the variance, positively correlated with land endowment, crop diversification index, and stored food stocks, but negatively associated with domestic labour land ratio. Comp1 described smallholders endowed with large per capita landholdings and food stocks but constrained in domestic labour. The second component (Comp2 - *young smallholders and higher welfare*), which explained 9% of the variance, was positively correlated to welfare (household expenditure) while negatively correlated with farming experience. Comp2 represented younger smallholders with less farming experience, likely to enjoy higher welfare. The third component (Comp3 - *labour endowment and less burdened*) also explained 9% of the variance with positive correlation with the number of adult members while negatively correlated with the dependency ratio. Comp3 represented farmers with more adult members to contribute to the household economy and have a lower dependency ratio. The fourth component (Comp4 - *commercially oriented*) accounted for 8% of the variance, positively correlated with the value of crops sales and hired labour. Comp4 represented farmers with resources who can afford to hire labour, buy inorganic fertilisers, and have higher annual crop sales. The fifth component (Comp5- *male and wealthy*), which explained 8% of the variances, was positively correlated with the gender of the households and wealth index. Comp5 described male-headed households with a higher wealth status compared to others. The sixth component (Comp6- *livestock rearing*) represents farmers with high endowments in livestock units and earned higher livestock income. The seventh component (Comp7- *usufructuary land rights*), which accounted for 7% of the variances, was positively correlated with usufructuary land rights. Comp7 represents farmers with relatively secure usufructuary land rights who either directly inherited their land or acquired it through cash transactions. Lastly, Comp8 (*extension access*) explained only 5% of the variability and was positively correlated with access to agriculture extension services. Comp8 represented smallholders with reasonably high access to agriculture extension services.

Table 4 Extracted principal components.

Variable	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	Comp 7	Comp 8
INFO_TEC	-0.03	0.26	-0.03	0.14	0.39	0.1	-0.16	0.13
GENDER	0.01	-0.05	0.05	-0.05	0.65	-0.06	0.06	-0.03
FRMG_EXPR	0.1	-0.58	0.02	0.03	0	0.05	-0.22	0.06
DEP_RATIO	-0.04	-0.02	-0.6	0.02	-0.04	0.03	0.1	0.09
EDUC_ENDW	0.07	0.31	0.37	-0.01	-0.29	0.11	-0.03	0.19
WEALTH_INDEX	0.04	0.25	0.02	0.07	0.4	0.07	-0.17	0.1
LAND_CONSTR	0.48	0	0.02	0.03	0.02	-0.02	0.05	-0.16
TENR_SCR	0.02	0.08	-0.06	0.04	-0.01	0.04	0.77	0.15
ECON_INDEP	-0.06	-0.09	0.61	0.04	0.06	-0.03	0	0.02
LOG_HHEXP_AEU	0.1	0.41	0.01	0.07	0.02	-0.01	0.1	-0.06
TLU	-0.01	-0.01	0	-0.06	-0.01	0.64	0.13	-0.12
CROP_SALES	0.22	-0.03	-0.04	0.47	-0.14	0.04	0.06	-0.1
LIVSTK_SALES	-0.02	-0.03	-0.03	0	-0.02	0.62	-0.09	0.05
ACC2_OFF_FARM								
\$	0.03	0.4	-0.18	-0.07	0.01	-0.1	-0.25	-0.08
EXTN_ACC	-0.02	-0.03	-0.01	-0.04	0.02	-0.04	0.11	0.82
PRODN_LVL	0.23	-0.09	0.05	-0.1	0.29	0.16	0.1	0.06
FERT_KGS	-0.04	-0.1	0.04	0.5	0.11	0.21	-0.01	0.06
DIVERSITY_INDE								
X	0.43	0.19	0.11	-0.12	-0.12	0.11	0.04	-0.08
LBR_HA-1	-0.49	0.13	0.2	0.01	-0.09	0.02	0.06	-0.01
HIRED_LBR	-0.06	0.04	0.01	0.67	-0.01	-0.14	0.03	-0.05
CREDIT_ACC	0.1	0.1	-0.12	0.1	-0.21	0.12	-0.4	0.33
LN_FOOD-								
STOCKS	0.44	-0.07	0.09	0.02	0	-0.18	0.01	0.2
Eigen Values	2.24	1.94	1.9	1.9	1.73	1.6	1.21	1.2
Cumulative variance explained (%)	10	19	28	36	44	51	57	62

Source: Own Survey, 2014.

3.3.2 The cluster analysis

The selection of the final cluster solution needs to be informed by the researcher's judgement, just as any empirical test (Hair *et al.*, 2014). Bidogeza *et al.* (2009) suggest that a final cluster solution also needs to be reasonable and interpretable. Since there is no single universally agreed-upon procedure to choose the number of clusters, the current study followed a similar method as other analysts to decide on the number of clusters to select (Köbrich *et al.*, 2003; Makate *et al.*, 2018b). The dendrogram (Figure 5) also provided useful graphic information on feasible options for cut-off points for a heuristic procedure to obtain the appropriate number of clusters together with expert knowledge of the area (Schonlau, 2002; Köbrich *et al.*, 2003). A five clusters solution was selected, marked by the red horizontal line on the Y-axis in the dendrogram (Figure 5).

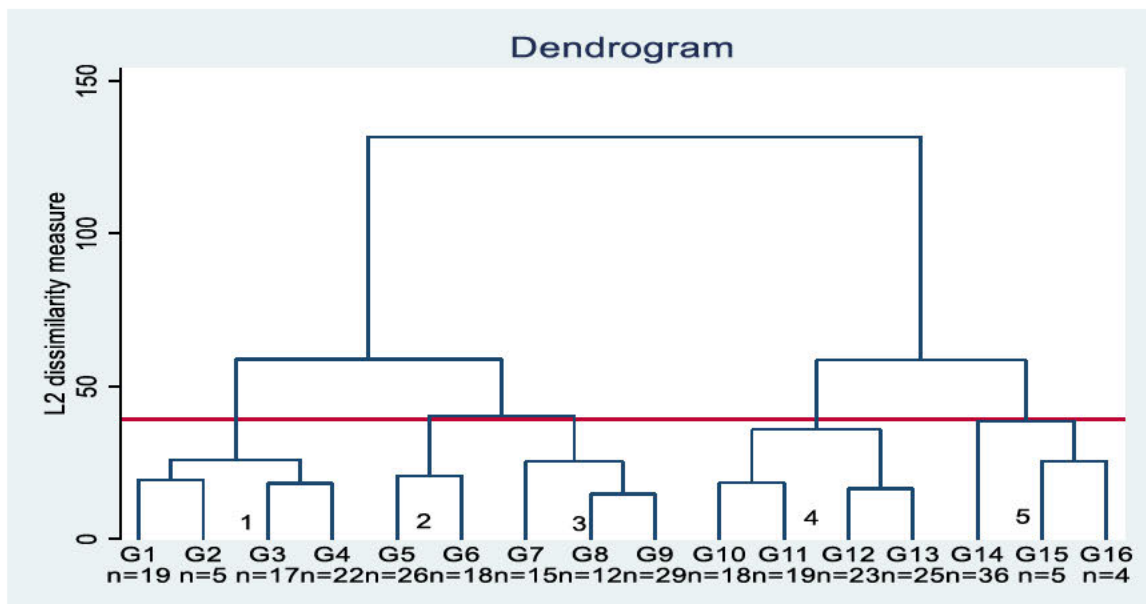


Figure 5.0 Dendrogram graphical representation from the hierarchical cluster analysis (Wald's technique).

Note: Branches censored at topmost 16. These branches are labelled G1 - G16 by default, and sample size $n = 1, 2, \dots, n$. A horizontal line marks the cut-off point for the selected number of clusters labelled 1 - 5.

Source: Own Survey, 2014.

3.3.3 The description of smallholder typologies

Table 5 results show the proportion of smallholders segregated by typology and the farmer category. For the total sample, typology IV was the largest cluster (29%), while type II (15%) was the smallest, like type V. There were significant variations in the distribution of smallholders based on the category of farmers. The trend was different in the *Jatropha* subsample (JCFs), as type I was the largest (28%) while type V was the smallest. The distribution of the population cluster centres by farmer category were statistically significant ($\text{Chi}^2 = 16.65^{**}$). The results suggest heterogeneity in the characteristics of smallholders based on the type of farmer category, which may have implications for targeting interventions to improve rural livelihoods.

Table 5 Percentage frequency distribution of smallholders by typology and farmer category

Farmer Category	Type I	Type II	Type III	Type IV	Type V	subsample size (n)
NJFs	18.5	11.5	18	33.5	18.5	200
JCFs	28	22.6	21.5	19.4	8.6	93
Totals (%)	21.5	15	19.1	29	15.3	293

Chi^2 test = 16.65**

Source: Survey data, 2014.

3.3.4 Characterisation of clusters

The characterisation of the composition of smallholders' typologies is a valuable tool to identify the constraints and opportunities for livelihood improvement of the clusters. Agroecological potential, resource endowments and market opportunities are crucial dimensions determining opportunities and constraints (IFPRI, 2007; Dunjana *et al.*, 2018). The one-way analysis of variance (ANOVA) procedure was used to study characteristics responsible for variations in the selected clusters (Hair *et al.*, 2014; Makate *et al.*, 2018a). The distinguishing attributes from ANOVA results were used to name the clusters (Makate *et al.*, 2018b; Makate *et al.*, 2018a).

The largest cluster for the total sample (29%) was typology IV (*Briefcase farmers*). The cluster's differentiating characteristics were primary occupation, gender, farming experience,

number of adult members, usufructuary land rights, and land constraint factors. The cluster members considered farming as their primary occupation (95%), primarily male-headed households (94%) with the second-highest number of years of schooling (6.7 years) as compared to the other groups. The smallest number of adult members per household (2.4 persons) and lowest labour to land ratio (2.5 persons ha⁻¹) was registered in this group. The landholdings, mostly under relatively secure usufructuary rights, were highest for members in this typology compared to other groups. Generally, the access to ICTs, level of input use, and agricultural income (livestock and crop sales) were second highest across all typologies. The higher levels of education and above-average access to off-farm income-earning opportunities, and value of non-farm incomes suggest that cluster members also have better off-farm jobs. 'Briefcase farmers are likely to be young professionals earning outside agriculture with an interest in farming. The off-farm income is invested in agriculture, farming cash crops for profit. 'Briefcase farmers' are unlikely to continue *Jatropha* cultivation in future considering that they are profit driven and the markets are not well developed. Furthermore, as others suggest, the proceeds from *Jatropha* cultivation ventures have remained relatively low (Kunda-Wamuwi *et al.*, 2017).

For the *Jatropha curcas* cultivating farmers' subsample, the distinguishing characteristics were gender, years of education, usufructuary land rights, diversity index, and access to off-farm income. The highest number of years of formal education, crop diversity, and access to off-farm revenues compared to all groups for JFCs were registered under this cluster. Despite having the least landholdings (2.4 ha) and labour to land ratio (2.5 persons ha⁻¹), the cluster ranked the second highest in agricultural equipment ownership (aggregate agricultural productivity). The cluster registered the highest percentage of usufructuary land rights, which indicated that members either bought most of their land or inherited it from their parents. The cluster members are constrained in domestic labour and may face labour shortages during peak demand periods like harvesting.

The land endowments, secure usufructuary land rights, farming experience, credit access and access to agricultural equipment present opportunities for pursuing interventions for livelihood improvement. The relatively low farming experience suggest that cluster members are younger and more likely to experiment and take up innovations. The land endowments, coupled with the relatively secure usufructuary land rights, indicates an opportunity for cluster members to pursue potentially profitable perennial crops beyond their traditional annual crops. The high

levels of credit access suggest that the members are creditworthy, which can be essential to invest in interventions that may need additional capital. Overall, the solid off-farm income base provides the opportunity to offset their domestic labour constraint by hiring labour and investing in fertiliser, which generated high crop sales compared to other clusters. Access to non-farm incomes suggests timely execution of farming operations and higher productivity, which comes with the ability to hire labour and purchase inputs (Kamanga, 2011). This typology mostly comprised medium to high resourced younger smallholders who can be described as young agricultural entrepreneurs. The typology members can be likened to semi-commercial and market-oriented smallholders (Kahan, 2013; Dunjana *et al.*, 2018). The members are also closely related to what another study described as “stepping up” smallholders (Dorward, 2009). Nonetheless, this typology had fewer JCFs (19.4%) as compared to NJFs (33.5%) (Table 5). Regarding *Jatropha curcas* cultivation, members in this typology may not be very enthusiastic about expanding the current investments due to their interest in profit-oriented production systems or may likely abandon the crop altogether (Kunda-Wamuwi *et al.*, 2017).

The second-largest cluster (21.5%) was typology I smallholders (*Agricultural labourers*). The differentiating characteristics for ‘agricultural labourers’ were labour endowment, land constraint factors, crop diversity and crop sales. The cluster comprised mostly of male-headed smallholders (90%), with the highest number of adult members (3.9 persons) who had the least landholdings (0.9 ha) across all clusters. The ‘agricultural labourers’ had the lowest crop diversification index (1.5) and received the lowest crop incomes compared to other clusters. The level of input use (chemical inputs, hired land, and labour) was also below the average for all clusters, which has implications for agricultural outputs and tradeable volumes.

The distinctive characteristics for the JCFs subsample were the number of adult members, land constraint factors, labour to land ratio, and crop sales. The number of adult members (4 persons) and labour to the land ratio (7.6 persons ha⁻¹) were highest in typology I, while crop sales were lowest compared to the other groups. Similarly, the members in the *Jatropha* subsample used below-average agriculture inputs (fertilisers and labour) compared to the other groups (Table 6). The ‘agricultural labourers’ were constrained in landholdings, credit access and lacked diversity in their production systems. Constraints in the *Jatropha* subsample were similar to the broader sample except for access to credit.

Nonetheless, the ‘agricultural labourers’ opportunities rested in their domestic labour endowment and high access to extension services for both the total sample and JCFs subsample. The limited land endowment overshadows the labour endowment for interventions that may need land availability to ensure the profitability of the investment. Nevertheless, domestic labour endowment is essential for labour demanding agricultural interventions and the management of peak demand periods such as harvesting (Mponela *et al.*, 2011). The ‘agricultural labourers’ were mostly male-headed households. The cluster had the third highest value in off-farm earnings. Overall, the results also indicated that the smallholders were resource-constrained despite having a high labour endowment. ‘Agricultural labourers’ were the largest cluster among the JCFs and had a higher proportion of smallholders than NJFs. The results in Table 5 showed that more JCFs (28%) were categorised as ‘agricultural labourers’ compared to NJFs (18.5%). The ‘agricultural labourers’ are primarily engaged in selling their labour to manage food security gaps when they run out of domestic production. Others use *ganyu* (informal or piece work) as a coping mechanism after shock encounters, especially in poorer households (Coulibaly *et al.*, 2015). The time spent on *ganyu* can potentially affect the smallholders' agricultural activities (Wood & Mayer, 2006). These results suggest that there were more JCFs engaged in such activities, which might affect the smallholders' resilience to food insecurity.

Table 6 Characteristics of selected variables for all sample and *Jatropha* subsample (parenthesis) in the clusters and p-values

Variable description	cluster 1	cluster 2	cluster 3	cluster 4	cluster 5	cluster mean	cluster SD	P-Value
<i>HH Demographics</i>								
Gender (1= maleheaded; 0= female)	0.9 (0.92)	0.66 (0.67)	0.23 (0.3)	0.94 (0.94)	0.71 (0.88)	0.72 (0.73)	0.45 (0.45)	0.000 (0.000)
Farmer (1= farmer; 0= otherwise)	0.86 (0.77)	0.82 (0.76)	0.95 (0.95)	0.95 (0.94)	0.93 (0.88)	0.91 (0.85)	0.29 (0.36)	0.048 (0.25)
Farming exprnce (years)	25 (26.2)	40.3 (36.9)	31 (32.6)	19.3 (17.8)	26.9 (27.1)	27.1 (28.4)	15 (15.9)	0.000 (0.0021)
Educn (years)	5.8(5.6)	3.9 (4.6)	4.7 (5)	6.1 (5.8)	6.9 (5)	5.6 (5.2)	0.5 (4.5)	0.000 (0.918)
Adult_members (persons)	3.9 (4)	2.5 (2.4)	2.7 (2.9)	2.4 (2.7)	3.6 (2.9)	3 (3)	1.3 (1.4)	0.000 (0.000)
<i>Land, labour, cropping</i>								
Landholdings (Ha)	0.9 (1)	1.4 (1.3)	1 (0.9)	1.6 (1.6)	1.9 (2.4)	1.3 (1.3)	1.1 (1.1)	0.000 (0.0088)
Usufruct land rights (%)	0.61 (0.53)	0.49 (0.41)	0.74 (0.79)	0.81 (0.91)	0.49 (0.5)	0.66 (.0.63)	0.46 (0.46)	0.000 (0.0019)
Landconstrnt (Ha)	0.16 (0.19)	0.26 (0.26)	0.18 (0.15)	0.34 (0.35)	0.32 (0.38)	0.26 (0.25)	0.24 (0.23)	0.000 (0.033)
Labour2 land ratio	6.8 (7.6)	3.01 (3.7)	4.49 (5.05)	2.48 (2.82)	2.86 (1.91)	3.94 (4.8)	3.28 (4.34)	0.000 (0.0002)
Diversity index	1.5 (1.8)	1.6 (1.6)	1.8 (2.02)	2.2 (2.5)	2.5 (2.5)	1.9 (2)	0.8 (0.7)	0.000 (0.000)
Agric_equipmnt index	-0.26 (-0.4)	-0.32 (-0.64)	-0.4 (-0.41)	0.22 (0.13)	0.86 (0.89)	0.01 (-0.24)	1.28 (1.01)	0.000 (0.0012)
<i>Access to services, ICTs</i>								
Access2 off-farm\$ (1= yes; 0 = no)	0.43 (0.54)	0.43 (0.57)	0.34 (0.3)	0.62 (0.67)	0.69 (0.5)	0.51 (0.52)	0.5 (0.5)	0.001 (0.229)

Variable description						cluster	cluster	P-Value
	cluster 1	cluster 2	cluster 3	cluster 4	cluster 5	mean	SD	
Credit (1= yes; 0 = no)	0.08 (0.12)	0.07 (0)	0.18 (0.05)	0.21 (0.11)	0.8 (0.5)	0.25 (0.11)	0.43 (0.31)	0.000 (0.002)
Extension (1= yes; 0 = no)	0.83 (0.69)	0.14 (0.1)	0.95 (0.85)	0.68 (0.56)	0.82 (0.75)	0.7 (0.570)	1.41 (.0.5)	0.000 (0.000)
Publicphones (minutes)	11.9 (14.3)	10.2 (11.7)	12.9 (18.9)	11.1 (11)	10.2 (16)	11.4 (14.2)	12.4 (14.8)	0.77 (0.48)
Radio (1= yes; 0 = no)	0.52 (0.34)	0.23 (0.19)	0.07 (0.15)	0.84 (0.89)	0.84 (1)	0.53 (0.43)	0.5 (0.5)	0.000 (0.000)
Television (1= yes; 0 = no)	0.02 (0)	0 (0)	0 (0)	0.13 (0.17)	0.18 (0.38)	0.07 (0.06)	0.25 (0.25)	0.000 (0.000)
Cellphone (1= yes; 0 = no)	0.52 (0.54)	0.25 (0.14)	0.2 (0.05)	0.78 (0.83)	0.89 (1)	0.55 (0.44)	0.5 (0.5)	0.000 (0.000)
Outcome/outputs								
TLUs	0.54 (0.95)	0.21 (0.21)	0.21 (0.25)	0.59 (0.91)	2.94 (11.9)	0.81 (1.57)	3.09 (5.33)	0.000 (0.000)
Wealth Index	0.044 (-0.19)	-1.18 (-1.21)	-1.42 (-1.22)	0.97 (1.03)	1.01 (1.46)	-0.003 (-0.26)	1.41 (1.38)	0.000 (0.000)
Totalivstcksales ('000 Mkw)	6.5 (5.6)	2.9 (4.0)	3.5 (4.5)	13.4 (19.1)	45.1 (90.1)	13.3 (14.9)	34.7 (38.9)	0.000 (0.000)
Cropsales ('000 Mkw)	5.8 (5.9)	31.6 (10.8)	9.2 (9.3)	37.9 (37.1)	91.1 (92.3)	32.7 (21.2)	82.4 (71.7)	0.000 (0.024)
Off-farm\$(value-'000 Mkw))	41.6 (58.6)	25.7 (35.8)	28.8 (24.9)	108.9 (145)	254. (126)	89.56 (68.7)	162.2 (142)	0.000 (0.000)
Input use factors								
Fert_use (1= yes; 0 = no)	0.78 (0.65)	0.8 (0.62)	0.75 (0.6)	0.85 (0.72)	0.93 (1)	0.82 (0.68)	0.39 (0.47)	0.131 (0.305)
Fert_kgs	79 (61)	63 (35)	58 (53)	94 (78)	198 (238)	95 (72)	108 (100)	0.000 (0.000)
Hired_lruise (1= yes; 0 = no)	0.21 (0.15)	0.16 (0.1)	0.16 (0.15)	0.31 (-0.33)	0.51 (0.63)	0.27 (0.22)	0.44 (0.41)	0.000 (0.013)
Hired_lbr ('000)	2.9(1.2)	2.7 (0.14)	1.6 (2)	4.8 (5.4)	18.8 (7.8)	5.6 (2.5)	18 (7)	0.000 (0.020)

Source: Own Survey, 2014.

As regards energy crops like *Jatropha curcas*, when they are planted on the boundary of farmers' fields and homesteads, they reduce competition for additional land with other field crops. The labour endowment in this typology can be essential to manage labour bottlenecks in pitting, harvesting and postharvest handling of *Jatropha curcas* seeds (Mponela *et al.*, 2011). Nonetheless, some agricultural interventions are generally more labour intensive than others; for example, cassava is relatively more labour intensive (142 days ha⁻¹ year⁻¹) as compared to *Jatropha curcas* in the first year under low input scenarios (91 days ha⁻¹ year⁻¹) (van Eijck *et al.*, 2012). Other interventions can be labour saving, such as the use of oxen where available to collect *Jatropha curcas* seeds (Kuntashula *et al.*, 2014).

The third-largest typology (*subsistence farmers*) comprised 19.1% of all smallholders. The cluster had gender, primary occupation, agricultural equipment index, wealth index, access to off-farm income, and level of input use as main distinguishing characteristics from other clusters. The cluster members were mostly female-headed (77%) who had the lowest durable asset base (wealth index = -1.42) as well as productive assets (agricultural equipment index = -0.4), which was indicative of low wealth status and agricultural productivity. Moreover, access to off-farm earning opportunities (34%) and level of input use (fertilisers and labour) were the least for this typology compared to others. The landholdings for the cluster members were below average (1 ha), which was mostly inherited land under relatively secure usufructuary land rights. Key informant interviews revealed that land was mostly under customary tenure, and ownership was passed on through a matrilineal inheritance system in the study areas. The ownership of livestock was also the lowest compared to other typologies, making them vulnerable to food security shock. Livestock sales smoothen consumptions when households face food security shocks and reduce the risk of asset liquidation (Lopez-Ridaura *et al.*, 2018). The distinguishing characteristics in the JCFs subsample included all the factors identified for the total sample, including off-farm incomes and landholdings, which were the least compared to all groups. The cluster members had the second-lowest livestock units across all the typologies. The 'subsistence farmers' were mostly female-headed, likely to be widows constrained in land endowments, agricultural equipment, assets (wealth-index), and had limited off-farm income-earning opportunities for both the total sample and JCFs. The asset endowments determine the choice of livelihood strategies for the poor (Mulugeta, 2009). The limited off-farm income-earning opportunities suggest limited human capital (tradeable skills) or economic opportunities for female-headed households (Sharaunga & Mudhara, 2016; Sharaunga, 2019). Generally, other than the relatively secure usufructuary land rights and very

high access to extension services, the members lacked the requisite capitals (labour and financial) to transform their lives for the entire sample and JCFs. The cluster can be described as mostly poor, older female-headed agricultural farmers, i.e., widows who lost their spouses due to natural death or the high HIV/AIDS prevalence in the area. The ‘subsistence farmers’ cluster members are consistent with production orientation associated with resource-poor and smallholder production systems. The ‘subsistence farmers’ cluster members can be described as either low-resourced smallholders or ‘hanging in there’ households reported by other studies (Dorward, 2009; Kamanga, 2011; Mutyasira, 2020). Overall, ‘subsistence farmers’ comprised more *Jatropha curcas* cultivating farmers (21.5%), which was the third-largest cluster in the JCFs subsample compared to NJFs (18%). ‘Subsistence farmers’ are more likely to continue tending to their *Jatropha* trees and collecting the seeds for the supplementary income that can support their livelihoods. The resource-poor smallholders tend to have diverse and complex means of earning their livelihoods. No matter how small they may seem, they play a significant part in their lives (Chambers, 1995).

Typology V (*commercial farmers*) comprised 15.3% of the total sample. The significant characteristics differentiating this typology, which were highest across all samples, were landholding, education, crop diversity, agricultural equipment, livestock ownership, access to off-farm income and credit. Access to ICTs, livestock sales, crop sales, and level of input use were the other factors differentiating this typology from others. The ‘commercial farmers’ cluster had below-average domestic labour to land ratio (2.5 persons ha⁻¹) and the lowest proportion of land under relatively secure usufructuary rights. In the *Jatropha* subsample, factors differentiating ‘commercial farmers’ from others were like all in the total sample mentioned above. Members in this typology are constrained in domestic labour; as such, they may endure labour shortage bottlenecks during seasonal peak demand periods (Dunjana *et al.*, 2018). The other constraint was insecure usufructuary land rights, which might have implications for long term land investments (such as soil and water management and perennial crops) (Sharaunga & Mudhara, 2016). The ‘commercial farmers’ cluster can be described as very high resource endowed smallholders with a strong commercial orientation. The ‘commercial farmers’ opportunities rest in the high resource base (land, labour, agricultural equipment, wealth, etc.) and high access to credit (80%). The multiplier effects created by backward linkages from investments of the ‘commercial farmers’ can provide labour opportunities to the ‘agricultural labourers’ and ‘subsistence farmers’. According to another study (Dorward, 2009), members of this typology can be likened to “stepping out” smallholders

who are wealthy. Nonetheless, the proportion of JCFs (8.6%) was lower by almost two-fold as compared to the share held by NJFs (18.5%) in typology V (Table 5). Generally, this typology of smallholders may not necessarily continue growing energy crops like *Jatropha curcas*, where returns remain unattractive at current yields and market conditions (Kunda-Wamuwi *et al.*, 2017).

The smallest cluster was typology II (*older uneducated smallholders*), which comprised 15% of the total sample. The distinguishing characteristics for this cluster were farming experience, level of education, off-farm income value, livestock sales value, credit, and extension access. The smallholders in this cluster had the highest farming experience (40.3 years), suggesting that they were older than other typologies. Their education level was also the lowest compared to other typologies. Access to extension and credit services was also the lowest compared to other typologies. The level of access to ICTs was also below average for all the clusters. The amount of income from off-farm earning opportunities was the least in this cluster compared to the rest of the clusters. The constraints for ‘older uneducated smallholders’ were education, credit, extension and insecure usufructuary land rights. Conversely, the ‘older uneducated smallholders’ had above-average access to land. Still, the low proportion of land under relatively secure usufructuary rights suggests that most of it were borrowed or rented land from owners.

In the *Jatropha* subsample, the differentiating variables from other clusters were farming experience, number of adults, usufructuary land rights, diversity index, agricultural equipment index, access to extension, access to credit, livestock units, livestock sales, level of fertiliser and labour use. All variables mentioned above registered the least values except for farming experience, which was the highest across all clusters. There were large differences in membership within the typology regarding proportional representation based on farmers’ category. There were twice as many *Jatropha curcas* cultivating farmers compared to NJFs in this cluster. The cluster was also the second-largest cluster for the *Jatropha* subsample (22.6%). This cluster can be described as comprising older and less educated smallholders with limited access to services. These results indicate that comparatively, there were more older-uneducated JCFs under this typology as compared to NJFs, which might have implications on the appropriate strategies for targeted livelihood improvement programmes.

The pattern of the results above is consistent with the literature in the context of adopting new agricultural technologies. Older farmers are relatively risk-averse, more inclined to tried and tested technologies, which generally produce fewer yields and generate lower crop incomes. Credit constraint has also been widely recognised as another determinant of the choices of crops and enterprises. Resource-poor smallholders are not considered credit-worthy mainly because of lack of collateral, determining crop or enterprise choices (Freeman *et al.*, 1998; Wood & Mayer, 2006). Education is generally acknowledged as an important determinant in the uptake of agricultural innovations. More educated smallholders understand information better and tend to be early adopters of innovations (Feder *et al.*, 1985).

Nonetheless, another study suggests that total household education endowment has a more substantial impact than the education of the household head in explaining the uptake of innovations. The evidence suggests there is an intricate role of education externalities of other household members in intra-household adoption decisions. As such, attempts to analyse constraints and opportunities for livelihood improvement, which considers only the education of the household head, may not be exhaustive or robust (Asfaw & Admassie, 2004). The important role of extension services in fostering the uptake of agricultural interventions is also well documented (Katengeza *et al.*, 2012; Kankwamba *et al.*, 2018). The Welch (1970) hypothesis argues that if gains acquired from education relate to the differential ability to interpret information, extension services can substitute education. For example, illiteracy does not hinder the transfer of information on new technologies using innovative approaches like a practical demonstration of a pilot program, farmer field school, etc. (Feder *et al.*, 1985).

The ‘older uneducated smallholders’ notably had above-average landholdings but were constrained in domestic labour. The labour to land ratio was also low (3 persons ha⁻¹) for all sample and the *Jatropha* subsample (3.7 persons ha⁻¹). Labour constraint would pose a serious challenge during peak periods such as harvesting *Jatropha curcas* seed which is the most demanding operation for JCFs. The second-lowest hired labour use (16%) was also observed under this typology, suggesting that they faced financial constraints.

3.5 Summary

Smallholders are neither resourced nor constrained in the same way. Heterogeneity is a real phenomenon among smallholders which renders ‘blanket’ recommendations on interventions for livelihood improvement less effective. This chapter aimed to analyse and compare sources of heterogeneity among smallholders and energy crop producers and determine typologies, opportunities, and constraint for livelihood improvement. The chapter applied multivariate analysis techniques to examine heterogeneity among smallholders using a dataset with energy crop producers.

This chapter's multivariate analysis (PCA and CA) results showed how heterogeneity renders blanket recommendations inappropriate and less productive. The findings identified and profiled five smallholder typologies, i.e., ‘agricultural labourers’, ‘older-uneducated farmers’, ‘subsistence farmers’, ‘briefcase farmers’, and ‘commercial farmers’. Other results showed that there was also heterogeneity in membership within the typologies between smallholders and energy crop producers. Overall, the results reaffirm that the smallholders were heterogeneous, which has to be accounted for in designing interventions for livelihood improvement. The various typologies present different opportunities and prospects for *Jatropha curcas* cultivation in the study area. The range of results across the typologies indicate a likelihood to continue for the majority of the sample (agricultural labourers (28%), older-uneducated farmers (23%), and subsistence farmers (21.5%)) and the possibility of abandoning the crops altogether (‘briefcase farmers’ (19.4%), and ‘commercial farmers’ (8.6%)) for others.

Chapter 4: The impact of *Jatropha curcas* cultivation on resilience to food insecurity in southern Malawi¹⁵

4.1 Introduction

Rural livelihoods in Malawi function in an environment characterised by pervasive risks, shocks, and uncertainties. Low agricultural production and productivity caused by, among others, small landholdings, low access to inputs and markets, weather-related shocks, and price volatility increases the vulnerability of rural livelihoods to food and nutrition insecurity (World Bank, 2007).

Weather variability, inconsistent rainfall in particular, is one of the sources of vulnerability in predominantly agricultural-based economies (Demeke *et al.*, 2011). In Malawi, weather variability threatens the livelihoods of 84 % of rural households dependent on agriculture, posing increased threats to food insecurity (National Statistical Office (NSO), 2018). In 2015, this condition caused a decline in the production of all major sources of starchy carbohydrates such as maize (30%), rice (18%) and cassava (2%) (Government of Malawi, 2016a). Agricultural systems need to adapt to these changes for them to be more resilient by transforming practices, diversification of the enterprises and crop species (Di Falco *et al.*, 2011; Kankwamba *et al.*, 2018).

The Malawi government is a signatory to international statutes such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The parties to these statutes are encouraged to enact laws, design legislative frameworks and implement adaptation strategies to address unfavourable impacts caused by climate change. (Government of Malawi, 2016b). The Malawi Government Growth and Development Strategy II (MGDS II) outlined, among other strategies, the increased use of renewable energy sources, increased agricultural productivity and diversification, as its key priority areas. Biofuels production delivers on two of the above objectives as renewable energy sources and crop diversification (Government of Malawi, 2012b; Government of Malawi, 2013; Romeu-Dalmau *et al.*, 2016).

¹⁵ This chapter is based on the following paper: Chamdimba, O.Y., Ortmann, G.F. & Wale, E. 2020. Resilience to shocks and food insecurity: determinants, and the impact of smallholder *jatropha curcas* cultivation in southern Malawi. *African Journal of Science, Technology, Innovation and Development*:1-15.

Crop diversification involves the choice of different crop species, including planting energy crops like *Jatropha curcas* for biofuels production (Wale, 2010; Government of Malawi, 2013). *Jatropha curcas* is a hardy deciduous crop that has low water use (Everson *et al.*, 2013). Smallholders in some districts of Malawi grow *Jatropha curcas*, an oilseed tree crop, to sell the seeds for biofuels production¹. In the early 2000s, the BioEnergy Resources Limited company (BERL) promoted *Jatropha curcas* cultivation in hedgerows and marginal lands to buy the *Jatropha curcas* seeds for processing biofuels. A recent study also reported positive gains in carbon sequestration from *Jatropha curcas* hedge-rows from BERL operational areas in Malawi (Romeu-Dalmau *et al.*, 2016).

The body of knowledge on how biofuels impact the livelihoods of smallholders in developing countries is steadily growing. Previous studies have analysed smallholders' food insecurity from a vulnerability perspective (Chaudhuri *et al.*, 2002; Bogale, 2012; Kakota *et al.*, 2015; Klasen *et al.*, 2015). There is a new and growing literature that applies an alternative approach of resilience to food insecurity (Alinovi *et al.*, 2010; Ciani & Romano, 2014; Gambo Boukary *et al.*, 2016). These two concepts, though related in some aspects, should not be confused as the same (Cutter, 2016). Vulnerability analysis aims at predicting the occurrence of a future risk such as poverty/food insecurity (Hoddinott & Quisumbing, 2003; Bogale, 2012). The resilience concept shifts the focus from long-term equilibria to creatively address system capacity to manage the effect of short-term perturbations and disturbances (Alinovi *et al.*, 2010). Daie and Woldtsadik (2015) argue that vulnerability and resilience are determinants of each other. Furthermore, the authors contend that the vulnerability approach presents the agents (households) and their role as rather passive, while resilience puts the household and their responses to stressors at the centre stage. Smallholders make rational decisions *ex-ante* or *ex-post* a shock-encounter, affecting resilience capacity and livelihood outcomes such as food security (d'Errico *et al.*, 2018; Ansah *et al.*, 2019). This study adopts the resilience approach because it focuses on assessing the capacities of the household as a decision-making unit to manage the effects of shocks (d'Errico *et al.*, 2018).

Despite the Malawi government making some strides to alleviate food insecurity more recently, the problem persists, and information on the factors that affect susceptibility to food insecurity remains somewhat limited (Kakota *et al.*, 2015). Since low or high household resilience to food insecurity increases or decreases the vulnerability to food insecurity, it is pertinent to investigate which population segments have low resilience levels and the determinants of the

resilience to food insecurity. The chapter's objectives are the following: (i) to identify the dominant shocks which affect smallholders, (ii) to analyse the distribution of smallholders' resilience capacity to food insecurity according to gender and farmer category, (iii) to investigate the determinants of household resilience to food insecurity, and (iv) to evaluate the impact of *Jatropha curcas* cultivation on resilience capacity to food insecurity.

The study results can be useful to inform climate change mitigation strategies, adaptation measures, and strategies to enhance resilience to food insecurity. This study is different from d'Errico *et al.* (2017), who combined quantitative variables with psychological aspects of well-being in measuring resilience in the following way. The current study used subjective measures of well-being alongside 'traditional' quantitative measures in defining household resilience to food insecurity.

This chapter analyses the determinant and the impact of *Jatropha curcas* cultivation on resilience against shocks among smallholders in Malawi. The analysis employed the endogenous treatment effects technique, which uniquely models the contribution of the selection (treatment) variable in the main outcome equation.

The rest of the chapter is organised as follows. Section 4.2 describes the methodology, which discusses the study area, sampling, and data collection (discussed in Chapter 3, sections 3.2.1 and 3.2.2), conceptual framework, and the empirical strategy used to analyse the objectives. The results and discussion of emerging issues from the analysis are presented in section 4.3. The summary of the empirical findings is presented in section 4.4, while the conclusion appears in chapter 6.

4.2 Study Methodology

The description of the study area, sampling, and the data were discussed earlier in Chapter 3, sections 3.2.1 and 3.2.2.

4.2.1 Conceptual framework

The conceptualisation of food insecurity has evolved over the years, which has informed how it is measured and the subsequent policy responses, such as addressing the lack of the physical commodity, access factors, and the nutritional and physiological insecurity associated with it (Sen, 1981b; Hendriks, 2015). There are several ways how food insecurity is conceptualised in

the literature. Among others, these include the Sen's entitlement and deprivation thesis, vulnerability to food insecurity, resilience to food insecurity, and poverty as a more long-term outcome (Sen, 1981b; Banerjee & Duflo, 2007; Alinovi *et al.*, 2008; Bogale, 2012; Hendriks, 2015; Ansah *et al.*, 2019). This study applied the theory of resilience to food insecurity to address its objectives as explained below.

The critical questions in the debate on resilience analysis are what constitutes resilience, how it is conceptualised and measured (Béné *et al.*, 2017; Ansah *et al.*, 2019). The household is considered as a component in a food system and a good entry point in the resilience analysis, which ultimately result in food security (FAO, 2016). To properly analyze the various causal pathways on how resilience capacity can influence/or affect food security, there is a need to separate the two and other related complex concepts like vulnerability (Ansah *et al.*, 2019). Resilience is a capacity, an intermediate outcome required to attain a higher developmental wellbeing goal such as food or nutrition security (Constas *et al.*, 2014).

The illustration in Figure 6 shows a conceptual framework adapted from various sources linking shocks, resilience capacity and livelihood outcomes. Shocks can be idiosyncratic (localised, e.g., illnesses) or covariate (widespread, e.g., drought), which impact on the resilience capacity, resilience-building strategies, and the livelihood outcomes of the affected households.

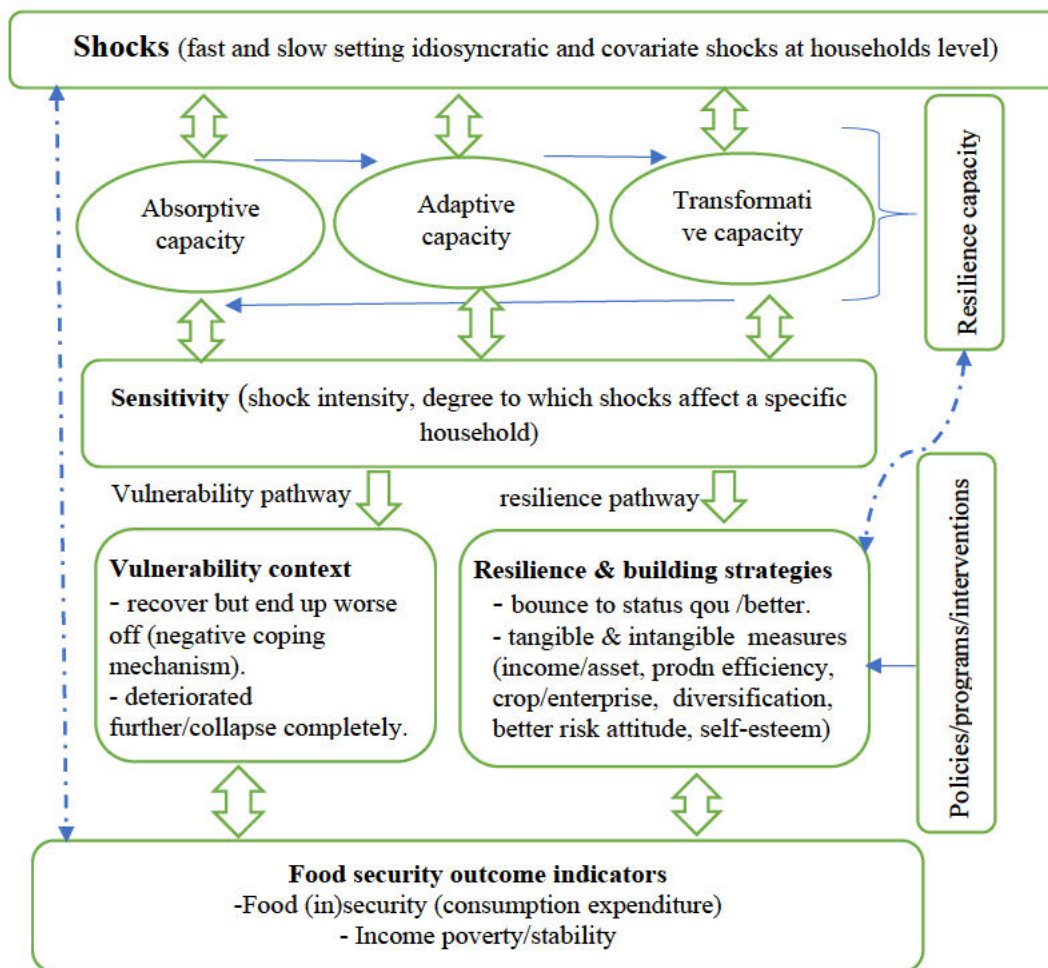


Figure 6.0 A conceptual framework linking shocks, resilience capacity, vulnerability and food (in)security outcomes

Source: a modified version of Ansah *et al.* (2019) and Frankenberger *et al.* (2012) .

Sensitivity is a function of the households pre-existing resilience capacity endowment (e.g., capital assets), which determines the impact of a given shock on the affected household unit. Following a shock encounter, depending on the coping mechanisms engaged, the household can fall on the vulnerability or resilience pathway. As emphasized by Frankenberger *et al.* (2012), the ‘pathway’ highlights the process aspect of the two concepts. Households that take the resilience pathway have less sensitivity, therefore, more resilient to food security shocks. Capital assets can eliminate the need for harmful coping mechanisms to mitigate the impacts of shocks and enable them to bounce back to the *status quo* or better. On the contrary, less sensitive households take the vulnerability pathway and equilibrate at a lower standing or destitute. The effects of shocks manifest as reduced productivity (animal and crops), poor

health (low labour productivity), insecurity, declining reserves and decline in welfare (Hoddinott & Quisumbing, 2003; Chiwaula & Waibel, 2009).

Analytical frameworks should capture all possible pathways that lead to resilience, linked to outcomes, and the risks faced by the agency in building their livelihoods (d'Errico *et al.*, 2018). The critical causal pathways for resilience building can target the absorptive, adaptive or transformative capacities, meaning either tangible or intangible measures (Béné *et al.*, 2012). Strategies that increase resilience capacity are comprised of both tangible and intangible means which unilaterally or together enhance the various attributes of the capacity. Tangible strategies aim at the building of assets/capitals, increasing efficiency in production and productivity. The focus for intangible approaches targets the agent's psychosocial behaviours like self-esteem, risk attitudes, aspirations etc. (d'Errico *et al.*, 2017; Ansah *et al.*, 2019). Interventions need to exploit the synergies and complementarities between the three resilience capacities to ultimately contribute to higher wellbeing outcomes (e.g. food security) (Béné *et al.*, 2012).

Smallholders construct a diverse portfolio of activities to earn a living (Wale, 2010). In this study, the household's decision to incorporate *Jatropha curcas* cultivation for biofuels production in their enterprise mix demonstrates an outcome of their choices. The various livelihood strategies are primary casual pathways used to build the household resilience capacity (tangible measures). Following Kemeze *et al.* (2018) and Hoque *et al.* (2015), smallholders' decision to cultivate *Jatropha curcas* can be examined using the random utility framework. In tandem with the random utility theory, a household decides to participate or not in *Jatropha* cultivation (programme/intervention) only if there are perceived as net positive utility benefits. Using notations, let participation and non-participation in *Jatropha* cultivation be denoted by g and h , and their expected utilities by U_g and U_h , respectively. The household decides to participate in *Jatropha* cultivation only if $U_g > U_h$. It is assumed further that the utility of a household's participation and non-participation in *Jatropha* cultivation is given by a vector of socioeconomic variables.

4.2.2 Empirical strategy

This study employed principal component analysis (PCA) to construct an aggregated household resilience index used as a response variable in further research. The endogenous treatment effect model was used to study the determinants and impact of *Jatropha curcas* cultivation on resilience to food insecurity.

4.2.2.1 Analysis of household exposure to shocks

The first part of the analysis was the identification of important shocks based on self-reported shock experiences. Following Chiwaula and Waibel (2009), smallholders were presented with a list of shocks to help them remember: they were asked if and when they had been affected by a shock, in the last decade to get a historical perspective of the frequent shocks affecting smallholders. Further analysis censored the data to shocks that occurred during the previous 12 months. Furthermore, additional detailed information was collected on the top three ranked shocks¹⁶ (d'Errico *et al.*, 2018). All reported shock incidences were coded as dichotomous variables and analysed using multivariate techniques. PCA was used to reduce the data dimensionality, identify the most important and dominant shocks. New shock variables were generated from principal components (Eigenvalues>1) and reclassified based on dominant factor loadings (Browne *et al.*, 2014). Section 4.2.2.2 below provides a more detailed discussion on the resilience index measure and its validation.

4.2.2.2 The resilience index measurement and validation

Resilience index measurement

Resilience capacity measurement involves interpreting abstract theories into quantifiable variables or indices and applying relevant econometric and statistical techniques to model household resilience to food insecurity. Resilience to food insecurity is unobservable *per-se*. There is no consensus yet on how it should be measured since its application to the development

¹⁶ The information collected on the recent shock in the previous 12 months were on, year, severity, costs of the shocks (treatment/replacement/lost income), and coping mechanisms. It was not possible at that time to capture adaptation costs due to the complexity of the subject.

field is relatively new (Jones & Tanner, 2015). Maxwell *et al.* (2016) contend that the mixed methods approach enables better explanation and prediction of the resilience outcomes. Resilience analysis requires the application of both objective measurements and the subjective assessment of the multifaceted relationships that relate to this concept (d'Errico *et al.*, 2017; Hirpo *et al.*, 2018).

Resilience estimation can be done using either a static (cross-sectional datasets) or dynamic (longitudinal datasets) framework. Panel data brings the temporal dimension in the analysis, but these data are expensive to collect and scarce, especially in developing countries (d'Errico *et al.*, 2016). Nonetheless, researchers have widely used cross-sectional data to study resilience to food insecurity in various parts of the world (Alinovi *et al.*, 2008; Daie & Woldtsadik, 2015). Resilience at the household level is defined as a capacity that ensures that shocks and stressors do not have long-lasting developmental impacts (d'Errico *et al.*, 2018). The three guiding principles to the measurement of resilience capacity to food security include (i) multidimensionality, (ii) whether it is constructed as a latent or observable variable, and (iii) resilience as an index measure (Constas *et al.*, 2014).

The FAO Resilience Index and Measurement Analysis (RIMA) framework and its updated version RIMA-II are promising models which apply the latent variable principle. RIMA employs factor analysis and Structural Equation Modelling (SEM) to assess resilience using observable indicators (d'Errico *et al.*, 2018). The RIMA approach is founded on four resilience pillars: access to basic services, assets, social safety nets, and adaptive capacity (FAO, 2016). The RIMA methodology is used widely to study resilience in various parts of the world (d'Errico & Di Giuseppe, 2018; Ansah *et al.*, 2019; Brück *et al.*, 2019).

Studies that apply resilience as a latent variable principle posit that resilience cannot be observed. Latent models assume that observable indicators represent an underlying latent concept, and other correlates influence the latent factors and exhibit a reciprocal effect. The 'latent variable models are hardly employed in inferential analysis' but are mostly useful for descriptive analysis of resilience and the contribution of the various selected correlates used to define resilience (FAO, 2016:22; d'Errico & Di Giuseppe, 2018). d'Errico and Di Giuseppe (2018:95) further comments that 'latent variable models reduce the possibility of inference. This affects the scope of the analysis that can be carried out and the consequent conclusions that can be drawn'.

On the other hand, the index measure attempts to construct a single measure of resilience from selected resilience attributes aggregated using multivariate techniques. Factor analysis and PCA are extensively used data reduction techniques that aim at extracting the first principal factor or component, representing the highest variation in the original dataset. The factor scores (eigenvectors) of the first principal component (PC) are used as the household's resilience index. The aim was to create a single index measure of the households' resilience to food insecurity (Browne *et al.*, 2014; Sinyolo *et al.*, 2014b). There are various merits of using an index measure to study resilience: it can facilitate comparability, ranking, targeting, the description of households and can also be used in further modelling exercises. Single measures of resilience on their own may have limited programmatic relevance; nonetheless, using an index does not preclude the use of individual variables. Indices can be a useful tool when used to investigate which individual variables or indicators explain heterogeneity in the household resilience capacities in the sample (d'Errico *et al.*, 2016). Based on the attributes mentioned above, the index measure was the preferred choice to study the determinants and impact of resilience capacity to food insecurity in this study.

The selection of variables to inform the resilience index needs to be informed by sound theoretical underpinnings, the researcher's knowledge, the experience of the area, empirical evidence, and the local context (d'Errico *et al.*, 2016). Resilience capacity indicators provide the platform for households to increase agency access or ownership of assets and services (Vaughan & Frankenberger, 2018). The classical approach is to use readily available key variables. This method avoids the problem of obscuring vital resilience patterns caused by complex indicators (Tefera *et al.*, 2017), as executed in other studies to explore heterogeneity in sampled households (Keil *et al.*, 2008; Lokosang & Ramroop, 2014; Gambo Boukary *et al.*, 2016). Following the approach of Gambo Boukary *et al.* (2016) and Tefera *et al.* (2017), the current study used polychoric PCA to aggregate the following resilience capacity attributes (i) income per adult equivalent, (ii) grain reserves (iii) livestock kept (TLU), (iv) durable asset index and (v) perceptions of the level of food security (Eqn 4.1) (see Table 7).

$$R_{it} = f(\text{INCM}, \text{GRNResrv}, \text{TLU}, \text{AST Index}, \text{FdProdn Lvl}) \quad i=1,2,3\dots n \quad (4.1)$$

Where R_{it} denotes the household resilience index, INCM was the annual household income from all sources per adult equivalent units, GRNResrv represents the value (Malawi *kwachas*)

of grain stocks reserved for domestic consumption, TLUs¹⁷ was total livestock units kept by household, AST was a durable assets index, FdProdn Level was the household's perception of their level of food production (explained further in Table 7).

Income is directly related to food access and how households absorb shocks. Income is also an important pillar in the FAO RIMA framework for measuring resilience to food insecurity. Households with higher incomes have a better economic capacity to purchase food and more likely to be more resilient to food security shocks (FAO, 2016; Kebede *et al.*, 2016). Households with higher grain reserves for domestic consumption are likely to be more resilient, especially when there is a physical shortage of food commodities (Tefera *et al.*, 2017). The importance of livestock in maintaining food security, especially for poorer households, is well known (Lopez-Ridaura *et al.*, 2018). Proceeds from livestock sales during lean periods of the year provide an option for smoothening consumption and sometimes provide productive-asset protection (Frankenberger *et al.*, 2012). Households with more livestock are likely to be more resilient and avoid poverty traps.

Durable assets are an indicator of long-term household wealth-standing in society. These households usually have multiple income streams and invest their proceeds in a range of valuable assets. Wealth is an important contributor to the asset pillar, strongly correlated to resilience (d'Errico *et al.*, 2018). Wealthier households have more durable assets and likely to be more resilient to food security shocks (Lokosang & Ramroop, 2014). Finally, to account for smallholders' perceptions on food security, households were asked to describe their level of domestic food production as surplus, adequate and not enough (Kebede *et al.*, 2016). Households which produce adequate to surplus food production are likely to be more resilient to food security shocks.

¹⁷ Tropical livestock unit is a widely used measure of livestock in equivalence of an animal of 250kgs regardless of species. For more details see: <http://www.fao.org/Wairdocs/ILRI/x5443E/x5443e04.htm>.

Table 7 Variables used for the resilience index

Variable	Description	Mean	SD
INCM	Annual household income earnings from all sources per adults equivalent units in Malawi kwachas ('000)	39.9	57.8
TLUs	Total livestock units ¹⁸	0.8	3.1
GRNResrv	Value of food stocks kept for home consumption per adult equivalent in Malawi kwachas ¹⁹ ('000) (production less sales of all food crops)	13.7	15.5
AST Index	PCA constructed aggregate index of durable household assets (radio, bicycle, furniture, beds, granaries, cell phone, etc.).	0.0021	1.41
FdProdn Lvl	Perception of household food security (1= food secure or 0 otherwise)	0.12	0.33

Source: Own Survey, 2014.

Validation of the resilience index

Testing if the resilience index was a good predictor of food consumption expenditure (welfare measure) is one way to validate it (Lokosang & Ramroop, 2014). Economic theory assumes that the household objective is to maximise utility subject to constraints, welfare, and the observable indicator is consumption expenditure (Glewwe, 1991). Linear regression is an appropriate model to test if a linear relationship exists between a continuous variable and predictors using the ordinary least squares (OLS) procedure. To test the above hypothesis, the following general linear model was used (Eqn. 4.2).

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 R_i + \beta_3 T_{ik} + \epsilon_i \quad (4.2)$$

Where Y_i is log food consumption expenditure per adult equivalent units (Ln FDexp), X_i is a vector of household demographics and other control variables, R_i is the resilience index, T_{ik}

¹⁸ Tropical livestock unit is a widely used measure of livestock in equivalence of an animal of 250kgs regardless of species. For more details see: <http://www.fao.org/Wairdocs/ILRI/x5443E/x5443e04.htm>.

¹⁹ The exchange rate at time of survey was 1 US\$= Mwk 390 (July 2014).

the k -th shock variable on i -th households, while ϵ_i is the error term, $\beta_0 \dots \beta_3$ are the intercept and parameter estimates, and ϵ_i is the error term. The coefficient of interest here is R_i 's parameter, which demonstrates if the resilience index is a good predictor of food consumption, holding all other factors constant.

4.2.2.3 The empirical model for assessing the impact of *Jatropha* cultivation on resilience to food insecurity

Sagara and Smith (2018) contend that the purpose of conducting a resilience study should guide the choice of the analytical method used to answer the study objectives. This study used the endogenous treatment effects (ETE) model to examine *Jatropha*'s impact on resilience to food insecurity. The ETE model was best suited for this study compared to other selectivity models such as the Heckman model, the reasons being (i) it addresses selectivity bias from self-selection in programme and non-randomness in the targeting of beneficiaries, and (ii) it models programme participation in the main model as a covariate (Greene, 2002). Considering that this study aimed at investigating the impact of *Jatropha* cultivation on resilience to food insecurity, ETE was the more suitable model for the task. The classical ordinary least squares (OLS) procedure would produce biased and inconsistent estimates of impacts of *Jatropha curcas* cultivation on resilience to food insecurity (Heckman, 1979). The instrumental variable approach is another way to deal with the endogeneity problem; however, good instruments are generally not easy to find (Verbeek, 2004).

The structural equation modelling (SEM) approach is a widely used technique to explain the various resilience dimensions' contribution in their respective pillars (Gambo Boukary *et al.*, 2016; d'Errico & Di Giuseppe, 2018; d'Errico *et al.*, 2018). As applied in the FAO RIMA methodology, the SEM and its variants are well suited for descriptive assessments and the contribution of various dimensions to the resilience construct. Nonetheless, regression-based approaches are necessary compared to SEM or latent variable methods to analyze the specific individual variables or determinants for recovery from a shock (bouncing back), which may inform policy (FAO, 2016).

In the treatment effects language, the endogenous treatment regression can be classified as a linear potential outcomes model, which allows for a specific correlation structure between

unobserved factors that affect both treatment and potential outcomes. The model comprises two equations, the outcome R_j (resilience index) and the endogenous treatment C_j (dummy for *Jatropha curcas* cultivation).

$$C_j^* = \gamma W_j + \varepsilon_j ,$$

$$C_j = 1 \text{ if } \gamma W_j + \varepsilon_j > 0, \text{ and } 0 = \text{otherwise} \quad (4.3)$$

Where C_j^* denotes the endogenous dummy treatment variable as specified above (Eqn. 4.3), w_j denotes covariates likely to influence participation in *Jatropha curcas* cultivation, γ are parameter estimates while ε_j represents the error term. The two-step procedure fits a probit model (selection equation) in the first step, then generates the parameter λ (inverse mills ratio), which is included in the estimation of the second step OLS procedure to correct for selectivity bias as illustrated below (Eqn 4.4):

$$R_j = \beta Z_j + \delta C_j + \beta \lambda_j + \mu_j \quad j=1,2,3\dots n \quad (4.4)$$

Where R_j denoted the household resilience capacity index, Z_j is a vector of control variables used to model the outcome, and C_j was whether a household participates in *Jatropha curcas* cultivation or not, λ_j is the inverse mills ratio, β and δ were parameter estimates. The error terms (μ_i, ε_j) are assumed to have a bivariate normal distribution with mean zero and covariance matrix Ω . The technical exclusion condition is required to improve the identification of the model (Verbeek, 2004; Heckman & Vytlacil, 2005). This restriction condition is relaxed when estimated using the control function method in the endogenous treatment effects model (Vella & Verbeek, 1999). The following resources provide a useful synthesis, developments, and empirical application on addressing sample selection bias (Maddala, 1983; Greene, 2002; Cameron & Trivedi, 2005).

There are two available options for estimating the ETE model using built-in functions (*etregress* command) in Stata 15 - the maximum likelihood and two-step methods. The maximum likelihood is the more efficient but stringent approach, while the two-step method relaxes the bivariate normality assumption making it robust though not necessarily efficient. The ETE model is widely applied in treatment effects and program evaluations (Greene, 2002).

4.2.3 Description of variables used in the empirical model

The list and descriptions of variables used in this study are presented in Table 13. The dependent variable used in the ETE model was the household resilience index generated using PCA, as described earlier in section 4.2.2. The resilience index was a composite measure representing household resilience scores. The households with extreme negative values (-1) on the spectrum show weak resilience capacity, whereas those in the positive region (going towards +1) imply the most resilience (Alinovi *et al.*, 2010; Daie & Woldtsadik, 2015).

The explanatory variables hypothesized to influence household resilience used in the empirical model were informed by the literature. The literature cites household demographics, biophysical conditions, resource endowments (assets), institutional factors, social safety-nets, and the vulnerability context as determinants of household resilience to food insecurity. The determinants can be grouped as absorptive, adaptive and transformative capacities (Alinovi *et al.*, 2008; Ulrich *et al.*, 2012; Gambo Boukary *et al.*, 2016; d'Errico *et al.*, 2017; d'Errico & Di Giuseppe, 2018).

Gender, dependency ratio, average household education, social status, and farming experience were the demographic factors used in the study. Studies indicate that men have more command over resources which can be invested to generate outputs, thereby increasing their resilience to food insecurity (Gambo Boukary *et al.*, 2016). Older smallholders (with more farming experience) may likely be more risk-averse and gravitate towards sustainability of production, therefore, unlikely to adopt innovations early (Qualls *et al.*, 2012). On the other hand, more experienced farmers have more robust networks, which guarantee them better access to information (on prices, credit access, outlets), services (markets, logistics, etc.) and opportunities as compared to young farmers (Kidane & Wale Zegeye, 2019). Farming experience's influence, therefore, was ambiguous *a priori*. Households with a higher proportion of working-age group members have more people contributing to the household budget. It was expected that households with more members in the working-age bracket would be more resilient to food insecurity shocks. Furthermore, families with higher education endowments are anticipated to process extension messages faster and adopt agricultural innovations quickly, thereby making them more resilient to shocks than others (Arouri *et al.*, 2015).

Similarly, better access to micro-credit, remittances, and social transfers cushions the households against food insecurity shocks, making them more resilient (McKenzie, 2003; Arouri *et al.*, 2015). Smallholders with access to off-farm income are likely to be more resilient since the additional cash streams to the household can be invested in farm inputs or smoothen consumption when faced with food security shocks (Asmah, 2011; Asfaw *et al.*, 2012b).

Access to basic services (school, water, hospital) and extension frequency were institutional factors used in the study. Better access to basic services is associated with dividends in labour productivity and quality of life which is likely to increase resilience to food insecurity (Alinovi *et al.*, 2010). The technology adoption literature suggests that agricultural extension services accelerate the uptake of new and more productive innovations by smallholders, increasing resilience to food insecurity (McCord *et al.*, 2015). Public phones were used as a proxy for the remoteness of an area in this study. Smallholders located in more remote regions face challenges to access input and output markets, which are likely to increase transactional costs. Smallholders in more remote areas are hypothesized to be less resilient to food insecurity shocks (Ulrich *et al.*, 2012).

Land constraint factor, soil fertility, crop diversity, agricultural equipment index, and coping strategy index were the resource endowment variables used in this study. Smallholders with higher access to land per capita can expand their operations to increase outputs to meet domestic production or market/sale demand. Furthermore, renting out unused land brings extra income to the household, increasing resilience to food insecurity (Mendola & Simtowe, 2015). Subjective soil fertility status was used as a proxy for land quality, which can determine the choice of an enterprise's crops and profitability. Smallholders having plots with low soil fertility will require added inputs to produce a good harvest. These smallholders are likely to be less resilient to food security shocks (Bogale, 2012; Tefera *et al.*, 2017). Smallholders who are closer to the power structures have been reported to have access to good land, which signifies social standing in the society (Tittonell *et al.*, 2010). Studies have also indicated that the agricultural equipment index gives an over-farm productivity measure. The agricultural equipment index was hypothesized to influence resilience to food insecurity positively. Households with more agricultural equipment (sprayers, ploughs, treadle pumps) enjoy increased efficiency of farm operations and are likely to produce better quality outputs (granaries, sprayers) (Günther & Harttgen, 2009). The coping strategy index accounts for the available options for the household to mitigate the impact of shocks. A reduction in harmful

coping mechanisms (lower coping strategies index) may serve as an indicator of overall household resilience to food insecurity (Béné *et al.*, 2017).

Lastly, stability, food stocks difference (weather shock proxy) were factors used to capture the vulnerability context. The economic impact of shocks caused by lost production, costs of replacing assets, or paying for medical care negatively affects household resilience to food insecurity (Alinovi *et al.*, 2010). The differences in stored food captured the impact of weather shocks compared between a ‘good’ and ‘bad’ year. Higher food stocks differences are expected to be associated with lower resilience to food insecurity. The previous year before the study, there were incidences of flooding, which generally reduced agricultural output in the study area.

4.3 Results and discussion

4.3.1 Some descriptive results

Table 8 below shows that JCFs were slightly older compared to NJFs. The average landholdings were not significantly different between JCFs and NJFs. The land constraint factor, which adjusts for the size of the household, suggests per-capita holdings were generally low (0.25ha/person). Almost half the sample had at least one member earning off-farm income. Access to credit was significantly lower among JCFs as compared to NJFs. The transformed log household food expenditure was significantly higher for NJFs than JCFs ($p < 0.1$). The other statistics are presented in the next section under variables used in regression analysis (see Table 13).

Table 8 General description of some of the data

Variable	Total sample (n = 298)	JCFs (n= 95)	NJFs (n = 203)	T-Test/Chi ²
Age (years)	45.6	47.7	44.6	1.61
Hhsize in adult equiv ²⁰ .	4.4	4.52	4.35	0.98

²⁰ Household size adjusted for age and gender of the household members.

Variable	Total sample (n = 298)	JCFs (n= 95)	NJFs (n = 203)	T-Test/Chi ²
Landholdings (ha)	1.3	1.3	1.4	0.77
Educnyrs (years)	5.4	5.2	5.7	0.95
TLU	0.81	1.53	0.47	2.82**
Credit (1=Yes)	0.25	0.11	0.32	15.3***
Off-farm\$ (1=Yes)	0.51	0.53	0.50	0.70
Ln FDexp ²¹	10.6	10.45	10.66	2.54*

Note: T-test used to measure the significance of continuous variables and Chi-Square test for categorical variables. Significance denoted at the following confidence intervals: * ($\rho < 0.1$), ** ($\rho < 0.05$) and *** ($\rho < 0.01$). Test statistics are absolute values. JCFs denotes farmers who cultivated *Jatropha curcas* in their enterprise mix, while NJFs represent non-*Jatropha* growers.

Source: Own Survey (2014).

4.3.2 Prevalence of reported risks and shocks affecting smallholders

The results on the prevalence of self-reported shock frequencies in the last ten years listed the most experienced shocks by smallholders. In the high impact shock category, the most frequently reported top three ranked shocks showed that suffering some form of physical trauma/disability (22%) was the most commonly reported shock, followed by high input costs (17%) and asset theft (15%) (Appendix A.1). However, further analysis concentrated on three top-ranked shocks experienced in the previous 12 months. More detailed information on the associated costs (treatment/lost income/cost of replacing assets), coping mechanisms, duration to recover etc., were also collected. The results showed that flooding (24%) had the highest reported frequency, followed by the death of a family member (23%) and high input costs (15%) (Appendix A.2). The key informant interviews with the agriculture extension officers revealed that the study areas registered above-average rainfall in the previous year, which caused flooding and generally affected agricultural production.

All self-reported shocks were captured as dummy variables. Further analysis was conducted using PCA to reduce the data dimensionality and capture the largest total variation in a few

²¹ Ln FDexp was constructed as the log value of all food consumed from own domestic production and market purchases. Domestically produced food was valued using prevailing market prices.

components. The PCA retained four-component loadings for dominant shocks (eigenvalues >1). The varimax rotated components were redefined as (1) Asset insecurity, (2) Crop and livestock diseases, (3) Job-loss and flooding, and (4) High input prices (see Table 9). The results showed that other than theft of assets, all other extracted components (shocks) directly affect livelihoods by eroding means of earning or producing food and lowering agricultural outputs, ultimately impacting welfare (incomes and food security).

Table 9 Varimax rotated component loadings for dominant shocks (eigenvalues >1)

Variable	Comp1	Comp2	Comp3	Comp4
Flooding	0.1816	-0.1175	0.4281	0.2514
Drought	0.2973	0.1918	0.3123	-0.2211
Livestock diseases	-0.0777	0.5646	0.1083	0.2717
Crop diseases	0.0274	0.5867	0.0027	0.0474
Asset theft	0.6149	0.0164	-0.0804	0.0056
Crop theft	0.3098	0.0552	0.3466	0.0951
Livestock theft	0.5353	-0.1012	-0.1226	-0.0003
Job loss	-0.1588	0.0403	0.6981	-0.1453
Death of family member	-0.1601	0.3265	-0.06	-0.4736
Input prices	-0.0381	0.2017	-0.1323	0.6966
Output prices	0.2428	0.352	-0.2399	-0.2687
%variation	0.1358	0.1249	0.1122	0.1055
Cumulative Variation (%)	0.1358	0.2607	0.3729	0.4784

KMO =0.55, Bartlett sphericity test (Chi2=125.8***).

Source: Own Survey, 2014.

Smallholders used various means to cope with shocks. Using their savings (27%) was the most frequently reported coping mechanism of managing shocks, followed by seeking extension advice (25%) and borrowing from informal sources (24.2%) (see Appendix A.3). Taking out formal loans was among the least reported means suggesting a lack of demand or smallholders rationed out of the credit market. The social networks (informal lending or borrowing) were one of the essential mechanisms in the management of shocks. Access to transfers in all their various forms (social capital) is a necessary means of safeguarding resilience to food insecurity

and fighting poverty in general for many households in developing countries (d'Errico & Di Giuseppe, 2018).

4.3.3 The household resilience index

This section presents the results of the construction of the aggregated household resilience index and its description. The Bartlett sphericity test for appropriateness of variables used to construct the resilience index for PCA ($\text{Chi}^2 = 119.7^{***}$) firmly rejected the null hypothesis that the variables were not correlated, suggesting they were suitable for PCA. The sample size of 298 was adequate based on the proposed rule of 10 cases for each variable used (i.e. minimum requirement was 50 observations) (Sinyolo *et al.*, 2014b).

The polychoric PCA was run on the selected variables to generate a single index representing the largest variation in the original covariates. The choice of polychoric PCA was motivated by the fact that the covariates used to generate the resilience index were numeric and ordinal, which otherwise violates the basic assumption for performing principal component analysis. The first principal component, representing the largest variation in the dataset, was used as the resilience index measure (Browne *et al.*, 2014; Lokosang & Ramroop, 2014). One principal component had an eigenvalue greater than one, but two principal components were extracted to show the differences in percentage variation explained by factors. The first principal component (Comp1) scores were used to generate an aggregated household resilience index. The results showed that the first principal component explained a larger proportion (38.4%) of the variation compared to the second (19.6%) (see Table 10).

The factor loadings on Comp1 showed dominance between the two extracted components. The Comp1 smallholders perceived their food production level as adequate, reserved more grain stocks and had higher incomes per AEU. Livestock units kept was the least dominant among all the variables in comp 1. The result suggests that livestock rearing did not necessarily guarantee food security but may only play a complementary role in cushioning against shocks which is consistent with the literature (Lopez-Ridaura *et al.*, 2018). Furthermore, the first principal component carried a much higher weight (inertia) in explaining total variation in the dataset. For this reason, it was used as the resilience index (Lokosang & Ramroop, 2014). The resilience index was used as a dependent variable in further analyses.

Table 10 Polychoricpca extracted principal factor loadings, and percentage explained

Variable	Factor1	Factor2
Income per AEU	0.4992	0.1043
Tropical Livestock Units	0.179	0.2187
Household Asset index	0.4783	0.1553
Level of food production	0.4525	-0.0265
Grain reserves	0.5835	0.0619
% variation explained	0.384	0.196954

KMO =0.70, Bartlett sphericity test ($\text{Chi}^2=119.7***$).

Source: Own Survey, 2014.

4.3.4 The description and distribution of smallholders' resilience index

A descriptive analysis of the distribution of households based on their resilience capacity scores is presented in Table 11. The results in Table 11 shows four categories (quartiles) of resilience capacity by gender and farmer category of smallholders. The households with lower levels of resilience were clustered in lower quartiles, while the more resilient ones were in the higher quartiles. The households were classified as belonging to the following resilience categories; (i) low (25th percentile), (ii) medium (50th percentile), (iii) high (75th percentile) and (iv) very high (>75th percentile).

The results presented in Table 11 showed that there were variations at the low and very high resilience categories. Overall, there were more JCFs (37%) categorised as having low levels of resilience compared to NJFs (20%). In the same category, almost twice as many female-headed households were classified as having low resilience capacity among JCFs (62%) compared to NJFs (28%). Similarly, large differences were also observed in the high resilience category with twice as many NJFs (28%) compared to JCFs (17%) clustered in the high resilience category. These results suggest that, generally, JCFs had lower resilience capacity, which rendered them more susceptible to shocks, especially in female-headed households. The Fisher's exact test results showed that the variations were significant for both JCFs ($\rho < 0.05$) and NJFs sample ($\rho < 0.1$).

Table 11 Distribution of smallholders based on resilience capacity scores by gender and farmer type

Gender/RCI category	Low	Medium	High	Very high	Subsample (n)
Male (%)	16	21	30	33	146
Female (%)	28	26	28	18	57
NJFs-%	20	22	30	28	203
Male (%)	28	30	20	22	69
Female (%)	62	31	4	4	26
JCFs-%	37	30	16	17	95

Source: Own Survey data, 2014.

The study applied typologies developed in Chapter 3 to get further insights into the heterogeneity of smallholders' distribution across the various resilience categories (see Table 12). The results showed that for 'agricultural labourers', more JCFs (38%) were in the lower resilience category than NJFs (22%). Furthermore, very few JCFs (10%) belonged to the high and very high resilience category compared to NJFs (30%). In Malawi, *ganyu* (informal or piece work) is widely used in rural areas as an *ex-post* shock coping mechanism, which is also closely related to deteriorating food insecurity conditions (NSO, 2012; Coulibaly *et al.*, 2015). These results suggest that JCFs are more likely to be at higher risk of food insecurity than NJFs. A recent World Bank report projects that casual workers like 'agricultural labourers' are likely to face a substantial reduction in incomes and consumption expenditure due to the COVID19 pandemic (Saldarriaga Noel *et al.*, 2020).

Table 12 The percentage distribution of smallholders by resilience category and typology

RCI category /typology	agric. labourers	older, uneducated farmers	subsistence farmers	briefcase farmers	commercial farmers	sample (n)
Low	22 (38)	48 (52)	47 (60)	6 (11)	0 (0)	37 (26)
Medium	46 (38)	22 (38)	25 (30)	19 (22)	3 (13)	23 (21)
High	22 (15)	30 (5)	22 (5)	34 (33)	38 (25)	36 (20)
Very high	11 (8)	0 (5)	6 (5)	40 (33)	59 (63)	67 (18)

Notes: Percentages for JCFs are presented in parentheses

Source: Own Survey data, 2014.

The ‘older-uneducated smallholders’ were twice as many among JCFs (23%) as compared to NJFs (11%) (Table 5). Further analysis showed that slightly over half of the JCFs were in the low resilience category compared to only 38% for NJFs. There were also fewer JCFs (10%) in the high to very high resilience category than NJFs (30%). These results suggest that more JCFs in this typology were likely to be affected by food insecurity shocks than NJFs.

A slightly higher proportion of JCFs (22%) was categorised as ‘subsistence farmers’ compared to NJFs (18%) (Table 5). There was a higher percentage of JCFs under the low resilience category outnumbering NJFs by almost 20% (Table 12). Compared to NJFs (28%), very few of the JCFs (10%) belonged to the high and very high resilience category suggesting that more JCFs were vulnerable to food insecurity shocks. The results in Chapter 3 characterised ‘subsistence farmers’ as resource-poor, which might constrain their options to increase resilience to food insecurity (Table 6).

As regards ‘briefcase farmers’, the results showed that there were more JCFs (25%) in the low to medium resilience category compared to NJFs (33%). Slight variations were observed in the high to very high resilience categories between JCFs and NJFs. In the last typology of ‘commercial farmers’, large variations were observed in the medium and high resilience category while the distribution in the very high resilience category was similar. However, Table 5 showed that there were fewer JCFs (7%) compared to NJFs (19%) categorised as ‘commercial farmers’. These results suggest that despite having similar proportions of

smallholders in the high to very high resilience category, only a few JCFs could be considered resilient to food insecurity shocks.

4.3.5 Determinants of resilience to food insecurity

The description of the variables considered in the regression analysis is presented in Table 13 below.

Table 13 Variables considered in the endogenous treatment regression analysis

Variable	Description	Sign	Mean	SD
Dependent variable				
RCI	Resilience capacity index (min. -1.137238; max. 4.126565)	DV ²²	6.68e-08	0.73
Explanatory variables				
Diversity index	Crop diversity index comprised of a count of crop species family (i.e. legumes, tree crops, etc.)	+	1.94	0.79
Stability	Represents all costs for crops, animals, and other income losses (such as expenses on chemicals, treatment of diseases, etc.)	-	-8.4e-10	1.0
AgricEquip ²³	Household's access index for agricultural equipment	+	-5.4e-4	1.39
Copingstrgys	Count of reported coping mechanisms used by a household (See appendix 2)	-/+	1.13	0.87
Gender	Gender of the household head (1= male; 0= female)	+	0.72	0.45
Dep_Ratio	Dependency ratio constructed as a ratio of economically inactive age members and total household size	-	0.49	0.23

²² DV denoted the dependent variable which was the resilience index in this study.

²³ The agricultural equipment index was constructed by aggregating the household's access to the following tools or machines: plough, sprayer, irrigation can, granary, treadle pump, oxcart, hand hoe and *panga* knife.

Variable	Description	Sign	Mean	SD
Avail.Labor	Domestic labour availability for agricultural activities adjusted for age and working status ²⁴ .	+	2.5	1.0
Farmexprnce	Years of farming experience	+/-	27	15
Landcnstrnt	Landholding per adult equivalent	+	0.25	0.24
Aveduendwnt	The average number of schooling years for all member (years)	+/-	3.8	1.8
Soilfert	Proxy for land quality, as a perception on the fertility of the land (1= fertile; 0 = otherwise)	+	0.27	0.43
FertUse	Quantity of fertiliser used in the last agricultural season	+	0.82	0.39
Social	Social club membership position (1 = Yes; 0 = No)	+/-	0.33	.47
Extn_freq	Extension contact frequency per month	+	1.8	2.4
Acces2bsrvcs	The distance in minutes for the household to access basic services ²⁵ .	+	1.7e-09	1.15
Publicphones	Distance in minutes to the nearest public phone (a proxy for the remoteness of the area)	-	11.2	12.3
StocksDiffnrcs	Proxy for weather shock ²⁶ .	+	-374	651
Off-farm\$	Access to off-farm income (1=Yes; 0 = No)	+	0.51	0.50
Credit	Access to credit (1=Yes; 0 = No)	+	0.25	0.43
REMMTC	Access to any form of remittances (1=Yes;0 = No)	+	0.03	0.17

Source: Own Survey, 2014.

The results presented in Table 14 show the two-step endogenous treatment effects model and OLS regression estimates of the determinants of household resilience to food insecurity. The

²⁴ Labour availability was calculated as follows: children < 9 years = 0, 9 to 15 years = 0.7, 16 to 49 years =1 and > 49= 0.7 (Runge-Metzger, 1988 cited in Kuntashula *et al.*, 2014). Furthermore, these units were further adjusted to account for the member's working status on the farm as follows: full time = 1 and part-time = 0.5.

²⁵ Public phone was used as a proxy for remoteness of an area. PCA was used to construct an index from time in minutes to nearest basic amenities, namely (i) waterpoint, (ii) public hospital, and (iii) trading centres.

²⁶ StocksDiffnrcs was constructed as the variance in food stocks kept for domestic consumption (kgs) between two consecutive years (2013/14). The previous year was associated with weather shocks (mainly floods).

dependent variable was the household resilience index regressed on a vector of household demographics, farm characteristics, and other socioeconomic factors. The model diagnostics summarised in the last rows of Table 14 showed that the *lambda* (λ) value (-0.209) was insignificant, indicating no evidence of selection bias, which could not be established *a priori*. In other words, unobservable factors did not affect program participation in *Jatropha curcas* cultivation. The *lambda* value suggests that the OLS estimates presented in the last columns of Table 14 for comparison purposes are unbiased and efficient. The models were a good fit for the data assessing the significant Chi-square (507***), F-statistic (19.78***) and the reasonably high R-square for a cross-section dataset.

The significant determinants of resilience to food insecurity with a positive sign were: Agriculture equipment index, land constraint, fertiliser use, education endowment, gender, coping strategies, credit access and access to basic services. Conversely, stocks difference (variance) and stability (income shock) were also significant and had the expected negative sign (see Table 14). The study results suggest that household resilience to food insecurity declined with experiencing weather variability and shocks with high economic impacts (e.g., catastrophic health expenditures). Resilience capacity increased with more credit access, landholding per capita, agricultural asset ownership, access to basic services, access to chemical inputs (fertilisers), average education endowment, and whether the household was male-headed.

Table 14 Determinants of household resilience: treatment effects and OLS estimates

Variable	Treatment effects		OLS estimates	
	Coef	St. Errors	Coef	St. Errors
AgricEquip	0.113***	0.03	0.092***	0.021
Landcnstrnt	0.588***	0.122	0.565***	0.141
FertUse	0.175*	0.069	0.171	0.077
Diversity index	0.059	0.049	0.09*	0.037
Soilfert	0.042	0.06	0.042	0.062
farmexprnce	-0.003	0.002	-0.002	0.002
Aveduendwnt	0.056**	0.017	0.054**	0.016
Dep_Ratio	-0.274	0.127	-0.289*	0.137
Avail.Labor	-0.038	0.03	-0.045	0.03

Variable	Treatment effects		OLS estimates	
	Coef	St. Errors	Coef	St. Errors
Gender	0.153*	0.069	0.176**	0.058
Off-farm\$	0.085	0.059	0.104*	0.06
Extn_freq	0.019	0.012	0.014	0.011
Credit	0.255*	0.11	0.17*	0.081
Copingstrgys	0.033*	0.016	0.032*	0.015
REMMTC	0.14	0.145	0.149	0.116
Acces2bsrvcs	0.052*	0.024	0.06**	0.022
Stability	-0.075**	0.025	-0.076	0.091
StocksDiffrcs	-0.001***	4.82E-05	-0.001***	-5.6E-04
<i>Jatropha</i> Cultvn	0.377	0.348	0.036	0.067
Constant	-1.02***	0.184	-0.946***	0.173
Mills ratios (λ)	-0.209	0.21		
Rho	-0.472			
Sigma	0.445			
Wald Chi ² (29)/F-Test	507.3***		19.78***	
Adj. R ²			0.646	
n	285		285	

Note: The results of the selection equation have not been presented in Table 14 in favour of OLS estimates to allow the comparison of results from the two models.

Source: Own Survey, 2014.

Male headed homes were likely to be more resilient as compared to their female counterparts. This result is consistent with previous findings by d'Errico and Di Giuseppe (2018). Access to basic services was positive and significant, highlighting the importance of support systems (infrastructure and institutions) that make livelihoods function. Better access to healthcare, schools and functional markets improves the quality of life and access to services that safeguard labour productivity, increasing resilience to food insecurity. This result is consistent with a previous study in Kenya (Alinovi *et al.*, 2010). Land constraints limit how much more land can be brought into production, setting the production frontier, which can impact household food security. More available land per adult equivalent was associated with higher levels of

resilience. This finding is consistent with a recent study that showed a positive relationship between landholdings and welfare outcomes (incomes and food security) (Mendola & Simtowe, 2015).

Fertiliser use had a significant positive influence on resilience capacity to food insecurity. Smallholders' access to inorganic fertiliser provides an opportunity to increase agricultural production. Inorganic fertilisers provide additional limiting plant nutrients and also increase land-use efficiency as an intensification strategy. Although fertiliser use increases agricultural outputs, other innovations are essential to increase its use efficiency and sustainability of production. The complementary agricultural technologies are organic manure, improved seeds, soil and water management technologies (including irrigation), and extension, among others (Mapila *et al.*, 2012b). Long-term strategies, which use more holistic approaches to counter this multifaceted problem of sustainable land use, are also important. The role of climate-smart agriculture (organic manure, agroforestry, etc.), while reducing the carbon footprint, can also be explored (Coulibaly *et al.*, 2017).

The coping strategy index had a positive and significant influence on resilience capacity. Generally, reducing harmful coping mechanisms is desirable to increase resilience to food insecurity (Béné *et al.*, 2017). A higher coping strategy index represented the range of options (both absorptive and adaptive capacities) available to the household to cope with shocks. Higher absorptive and adaptive capacities are essential attributes to increasing resilience against food insecurity. The adaptive capacity reflects the learning aspect of resilience-building. The dimensions of adaptation can be implemented *ex-ante* or *ex-post* shock encounters (Carpenter *et al.*, 2001; Neil *et al.*, 2011).

Smallholders rely on a portfolio of strategies to manage shocks (Harrower & Hoddinott, 2005; Levine *et al.*, 2011). Others suggest that disentangling the multiple coping mechanisms is rarely possible and may be of little consequence for policy intervention (Levine *et al.*, 2011), making the local context important. Following Alinovi *et al.* (2008), the coping strategy index was constructed as a count of coping strategies used by the smallholder. The results on the frequency distribution of shocks experienced in the previous 12 months showed that most were agricultural-related (livestock and crop diseases (17%) and flooding/dry spells (31%) (Appendix A.2). Smallholders mostly used their savings (27.5%), followed by seeking extension advice (25%) to cope with shocks (Appendix A.3). The agricultural extension staff

provided technical advice on the management of agricultural-related shocks. Financial instruments (savings and informal money lending) were the most frequently reported means of mitigating the impacts of shocks. Savings is an essential attribute of the absorptive resilience capacity which can protect the productive assets and avoid falling into poverty traps. These results suggest that there is a need to strengthen support systems used by smallholders to increase resilience to food insecurity.

The negative influence of stability (income shock) underscores the importance of shocks with high economic impacts. The most frequently reported shocks perceived to have had the highest impact in the previous 12 months were flooding (24%), death in the family (23%), and an increase in input prices (13%) (Appendix A.2). The financial implications caused by these shocks can pose a considerable burden on livelihoods and threaten household food security. Shocks can erode assets and, in extreme cases, lead to poverty traps. Catastrophic health expenditures and unfavourable weather events can force households to liquidate productive assets, sometimes in dire circumstances at lower than acquisition value. The effect of uninsured risk, as is the case mostly with smallholders, can distort livelihoods permanently. The role of practical risk management strategies before shocks occur, such as early detection of developing risks, their subsequent reduction, or the total elimination of identified hazards, need to be explored (HLPE, 2013b). Less costly strategies that reduce risks, such as promoting disease-tolerant animal breeds and disease-resistant and drought-tolerant crops, need to be encouraged to increase resilience to food insecurity. Other mechanisms can consider transferring risks through insurance policy instruments like rainfall indexed agricultural insurance (HLPE, 2012b; Barrett & Conostas, 2014).

The agricultural equipment index was used as a proxy for the aggregate agricultural productivity of the household, which may be difficult to observe through the individual assets (Günther & Harttgen, 2009). The results showed that productive agricultural assets positively and significantly affected household resilience capacity to food insecurity. Farm equipment enables smallholders to increase farm production and productivity by increasing the scale and efficiency of farm operations. Increased use of farm tools can reduce drudgery, especially in labour constrained female-headed household. The ownership and use of tools like sprayers are necessary for crop protection and improve the quality of agriculture products. Mangochi is a lakeshore district where many smallholders are also engaged in other livelihood activities like fishing activities. The potential competition for limited resources caused by needs in the other

livelihood activities (e.g., fishing gear) may limit investment in agricultural equipment. Infrastructure like granaries reduces post-harvest losses and enables food to be stored for longer durations, to be consumed or sold later when prices are more attractive. The ability to store food and the opportunity to pick times to trade contributes to increasing resilience to food insecurity at the household level. This result collaborates with a previous study on the role of assets in enhancing resilience to food insecurity in South Sudan (Lokosang & Ramroop, 2014).

Credit access was positive and significantly influenced resilience to food insecurity. Access to credit increases the consumption of inputs like fertilisers and chemicals for increasing agricultural outputs and crop protection. In this study, further analysis showed that, overall, smallholders who accessed credit reported significantly higher average fertiliser consumption (138kgs) than their counterparts (80.4kgs) (t-test $p < 0.0001$), which has implications on yields and resilience to food insecurity. Overall, only about a quarter of the sampled household had accessed some form of credit in the previous 12 months. This result suggests that the poor rationed themselves out of the credit market or they were not credit-worthy. Focus group discussions with farmers revealed that there were just a few project-based (one government-funded project and two donor projects) financial service providers operating in the study areas. One of the constraints to agricultural production highlighted in focus group discussions was low input use. Innovative microfinance solutions such as village banking models (e.g. village savings and loans) have been reported as another source of rural incomes and credit, especially in remote areas (Nyambane *et al.*, 2020). Increased coverage of such innovative solutions could serve a diverse typology of smallholders, which could avail resources to invest in agricultural inputs to improve outputs and resilience to food insecurity. This result is consistent with previous empirical evidence from Rwanda, which found that credit access increased agricultural productivity (Taremwa *et al.*, 2021).

Human capital measured as household education endowment had a positive and significant influence on resilience capacity to food security shocks. A possible explanation could be that households with higher education endowment would contribute more to the household budget than those with fewer years of education. Moreover, an educated domestic workforce is more likely to understand better and translate agricultural extension messages which can lead to higher outputs. Consistent with economic theory, higher education endowment levels for the family suggests that these households benefit from increased productivity and opportunities to access better paying non-farm work (Lewin *et al.*, 2012).

Weather shocks had the expected negative sign and significantly lowered resilience to food insecurity. As expected, higher food stock differences were expected to decrease household resilience capacity to food insecurity. Focus group discussions and key informant interviews revealed that the weather shocks were primarily attributed to the flooding incidences experienced in the previous season. Almost a third of the reported shocks frequencies in the high severity category was associated with weather variability (floods/droughts and dry spells) (Appendix A.2). Other than the physical damage to assets, flooding removes significant quantities of nutrient-rich topsoil, which reduces soil quality (Thulstrup, 2015). The poor-quality soils impacts on adaptive capacity (asset quality), which affects the ability to produce food and eventually impact on food security. Increased access to quality early warning systems information on weather variability (floods/droughts) can help early detection and reduce the risks of shock exposure. These results also emphasize the need for policy to promote climate-smart agriculture and climate change adaptation strategies to increase household resilience to food insecurity. These findings are consistent with other studies which found that weather-related shocks (floods) were associated with a drop in welfare (Tesliuc & Lindert, 2002; Arouri *et al.*, 2015).

The coefficient δ measured the impact of *Jatropha curcas* cultivation on resilience to food insecurity on the dummy variable for *Jatropha curcas* cultivation in the outcome equation (Eqn 4.4). The unique feature of the endogenous treatment effects model includes the treatment dummy variable as a regressor in the second step of estimating the outcome model. The results showed that *Jatropha curcas* cultivation was not significant for both the endogenous treatment effect and OLS models (Table 14). These findings are consistent with the distribution of smallholders' resilience scores which found that most JCFs (36%) were clustered in the low resilient category compared to NJFs (20%) (Table 11). The domestication of *Jatropha curcas* as a complementary high-value crop is relatively new compared to other crops (Edrisi *et al.*, 2015); dividends of its further development (productivity and marketing) may likely benefit the less resilient households.

4.3.6 Validation of the resilience index

The effect of shocks on the selected food security measure (food consumption expenditure per adult equivalent) was conducted by the OLS estimation of equation (4.2). The model was

estimated with robust standard errors to remedy heteroskedasticity (Breusch-Pagan $\text{Chi}^2 = 17.87$; $\text{prob} > \text{Chi}^2 = 0.000$). The variance inflation factor was also low for the food security model (VIF= 1.2), suggesting that the model had no multicollinearity problems. The models showed a good fit for the data considering the significant F-statistic ($F = 9.88^{***}$) and reasonably high R^2 for cross-sectional data (Appendix A.4).

The validation of the resilience capacity index (RCI) was done to test if the composite index was a good predictor of food security measured as consumption expenditure per AEU. Table 15 below showed that the aggregated resilience index was positive and significantly influenced food consumption expenditure per AEU. The result confirmed that the resilience index was a good predictor of food consumption expenditure per AEU. The findings indicate that the aggregated index was a robust measure of household resilience to food insecurity.

Table 15 The effect of RCI on food consumption expenditure per AEU

Variable	FDexp/AEU
Resilience capacity index	
RCI	0.28*** (0.037)
Shocks and Pc-components	
Stability	-0.065* (0.037)
StocksDiffrenc	-1.26e-04* (5.4e-5)
Pc_ Asset insecurity	-0.002 (0.023)
Pc_ Crop and livestock diseases	0.021 (0.025)
Pc_ Job-loss and flooding	-0.012 (0.024)
Pc_ High input prices	-0.015 (0.028)
Farm and HH control characteristics	<i>Yes</i>

Note: Household control variables were omitted in this table. The full table was presented in (Appendix A.4).

4.4 Summary

The chapter analysed the determinants of resilience to food insecurity and the impact of *Jatropha curcas* cultivation on household resilience to shocks and food insecurity among smallholders (growers and non-growers of energy crops) in Southern Malawi. The endogenous treatment effects model was chosen because the decision to participate in *Jatropha curcas* cultivation can potentially be endogenous, introducing bias in the assessment. Furthermore, the ETE models capture the impact of the bivariate participation variable in the main equation (resilience capacity index).

The findings of this chapter showed that resilience to food insecurity was associated with being a male-headed household, better access to assets /endowments (land, agricultural equipment, inputs-fertiliser, and education endowment), and services (credit, coping strategies, and basic services). On the other hand, higher economic costs of shocks (stability) and high variance in the value of stored food crops between a ‘good and bad’ year (a proxy for weather variability) negatively impacted on resilience to food insecurity. Furthermore, the study also found that *Jatropha* cultivation had no effect on resilience capacity to food insecurity as compared to their counterparts.

Chapter 5: Biofuels and rural livelihoods: empirical evidence on the welfare impacts of *Jatropha curcas* cultivation in southern Malawi²⁷

5.1 Introduction

Agriculture plays a significant role in the economy of Malawi. It contributes up to a third of the country's gross domestic product and employs over 60% of the total labour force (Government of Malawi, 2013; NSO, 2014). Arable crop farming is a primary source of livelihoods, complemented by livestock rearing in most rural areas of the country. The majority of the population (86%) is rural-based (NSO, 2012; NSO, 2014).

Biofuel feedstock production is an agricultural activity. The recent prominence of biofuels internationally and in sub-Saharan Africa has been attributed in the literature to crude oil price volatility and national energy security, new market opportunities, climate change mitigation, foreign exchange savings, and the potential to transform the rural economy (Jumbe *et al.*, 2009; Mudombi *et al.*, 2016).

Malawi has consistently blended fossil fuel with bioethanol from sugarcane molasses since the 1980s, while biodiesel blending followed only recently. The extensive cultivation of *Jatropha curcas* as a high-value tree crop for biofuels production only gained momentum much later (the early 2000s). *Jatropha curcas*²⁸ is one of the biofuel crops that gained prominence due to its many attributes such as (i) its low management requirements, (ii) adaptability to marginal lands, and (iii) the fact that it is not a food crop. These attributes led to the creation of ambitious targets in developing countries to attract foreign investors. Most governments in Sub-Saharan Africa (SSA) have existing or proposed biofuel blending mandates of up to 10% (Jumbe *et al.*, 2009; Jumbe & Mkondiwa, 2012; Gasparatos *et al.*, 2015). At the peak of the *Jatropha* hype in the early 2000s, SSA was estimated to have contributed 13% to the total global land under *Jatropha curcas* cultivation (Brittaine & Lutaladio, 2010; Kant & Wu, 2011).

²⁷ This chapter is based on the following paper: Chamdimba, O.Y., Ortmann, G.F. & Wale, E. 2019. Biofuels and livelihoods: empirical findings on the welfare impacts of *Jatropha* cultivation in southern Malawi. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 120 (2):129-140.

²⁸ *Jatropha curcas* is a tropical oil-seed tree crop, which grows well in low altitude areas (0 to 500m) and tolerates moderate annual rainfall conditions (300 to 1,000mm). The seeds have a high oil content, which can be extracted and used as a straight vegetable oil or blended with fossil fuel (paraffin or diesel) to make biofuels (Achten *et al.*, 2008; Makungwa *et al.*, 2013).

Smallholders' participation in the biofuels value chain is in feedstock production as wage earners (industrial plantation) or as out-growers selling *Jatropha curcas* seeds (Achten *et al.*, 2008; Achten *et al.*, 2010). *Jatropha curcas* can be cultivated as a monocrop (as in plantations) or as hedgerows around farmsteads and homes. Traditional uses of *Jatropha curcas* never warranted the application of scientific knowledge to improve the economic importance of the crop; to a considerable extent, it has been promoted as a developmental crop with untapped potential (Brittaine & Lutaladio, 2010). In Malawi, Bioenergy Resources Limited (BERL), a private company, was one of the prominent stakeholders who invested resources (extension materials and staff) to promote *Jatropha curcas* cultivation. Smallholders in the targeted areas were encouraged to grow *Jatropha curcas* in hedgerows around boundaries of their fields and on marginal lands for biofuels production, amidst concerns of potential conflict with food security (Mponela *et al.*, 2011; von Maltitz *et al.*, 2014).

Arguments surrounding negative externalities caused by biofuels promotion, including land tenure security, indirect land-use change and food security concerns, remain extensively debated issues (Ajanovic, 2011; Mwakaje, 2012; Pradhan & Mbohwa, 2014). Nevertheless, others argue that a delicate balance exists within certain thresholds that limits the carbon debt depending on the types of feedstock and production practices used (Romeu-Dalmau *et al.*, 2016; Schuenemann *et al.*, 2016). Despite the collapse of many previous biofuel projects across Africa (mostly industrial plantations), a few *Jatropha* projects survived, like the case of some plantations in Mozambique and out-grower schemes in Malawi (Gasparatos *et al.*, 2012; von Maltitz *et al.*, 2014; von Maltitz *et al.*, 2016).

In Malawi, rural livelihoods mainly depend on traditional cereal crops like maize (staple food), legumes such as beans and groundnuts, and limited cash crops such as tobacco, cotton and tea depending on agroecological zones. The growing of *Jatropha curcas* as a feedstock by smallholders in the targeted areas contributes to crop diversification in the enterprise mix (Nalivata & Maonga, 2011; Government of Malawi, 2013).

5.2 Rationale of the study

A few studies exist on biofuels in Malawi. Previous *Jatropha* research has focused on areas like policy, awareness, small-scale processing, adoption, and socioeconomic impacts, among others (e.g. Jumbe *et al.*, 2009; Mponela *et al.*, 2011; Nalivata & Maonga, 2011; von Maltitz *et al.*, 2014; Gasparatos *et al.*, 2015; Mudombi *et al.*, 2016; von Maltitz *et al.*, 2016). The literature on socioeconomic impacts of biofuels cultivation at the local level has largely remained theoretical, qualitative and has not addressed sample selection bias (Hodbod & Tomei, 2013; Mudombi *et al.*, 2016). Farmers can self-select or stakeholders target interventions to specific areas, potentially causing selection bias. A quantitative study on the impact of *Jatropha curcas* cultivation on smallholders' livelihoods that addresses sample selection bias in Malawi has not previously been conducted. Failure to account for selection bias in the estimation of outcomes might lead to under or over-estimation of the effects of biofuels promotion at the local level. With the publicity of the promise of biofuels to deliver on the rural development agenda, this empirical study is well justified (Ewing & Msangi, 2009; Ambali *et al.*, 2011; Herrmann *et al.*, 2017).

The current study aimed to provide empirical evidence and rigorous quantitative analysis of the impact of *Jatropha curcas* cultivation for biofuels production on smallholders' welfare in the Mangochi District of southern Malawi. More specifically, the study evaluated the poverty profiles of smallholders cultivating *Jatropha curcas*. Secondly, the study investigated the determinants of smallholder welfare at the local level, measured as consumption expenditure per adult equivalent unit (AEU). Lastly, the study evaluated the welfare impact of *Jatropha curcas* cultivation on smallholders.

The current study differs from an earlier study (Mudombi *et al.*, 2016) in various ways. Firstly, the current study applied rigorous econometric techniques that account for sources of selectivity bias caused by non-randomness in the identification of smallholders cultivating *Jatropha curcas*. Secondly, this study used consumption expenditure per AEU as a measure of household welfare widely used in welfare studies (Asmah, 2011; Sinyolo *et al.*, 2014a). Consumption expenditure per AEU was chosen as a suitable indicator for such investments that are relatively new compared to the multidimensional approach (adopted by Mudombi *et al.*, 2016), which uses semi-durables (assets). The choice of consumption expenditure over

income draws from well-documented merits of its reliability and relative ease in capturing the data (Deaton, 1997).

This chapter presents the analytical framework and empirical evidence of welfare impact assessment of *Jatropha curcas* cultivation in southern Malawi. The analysis used poverty indices, propensity score matching and switching regression techniques to analyse the study objectives. The findings of this chapter informed the conclusion and policy implications for advancing future policy direction on biofuels development in Malawi.

The rest of the chapter is structured as follows. The following section 5.3 covers the study methodology, which describes the empirical strategy used to answer the objective. The data and study site were presented earlier in Chapter 3, section 3.2.2. Section 5.4 presents the analysis results, followed by a discussion. The results summaries for the chapter are presented in section 5.5, while conclusions and recommendations are in Chapter 6 at the end.

5.3 Methodology

The description of the study area, sampling, and the data were discussed earlier in Chapter 3, section 3.2.

5.3.1 Theoretical framework

The participation in the growing of energy crops was conceptualised using the innovation adoption hypothesis based on the random utility theory. According to the random utility theory, smallholders' seek to maximise utility from the choice of participating in growing energy crops and other incentives that come with the decision. Let participation and non-participation be denoted by m and n and their expected utilities by U_m and U_n , respectively. The smallholders decide to participate in growing energy crops if $U_m > U_n$. Smallholders will only participate in growing energy crops if there is a net positive gain from the participation, meaning that the benefits and incentives are higher than the costs and disincentives. Since utilities for both participation and non-participation are unobservable, it can be perceived that smallholders participating in growing energy crops receive benefits that are not enjoyed by non-participating households.

The comparison of descriptive statistics on outcome variables (such as income or expenditure) can be used to assess the effect of participation in growing energy crops (Chirwa *et al.*, 2017). However, the decision to participate in growing energy crops is non-random since smallholders can self-select, or a defined targeting criteria can be used to identify the beneficiary. The non-randomness in selecting observation units is a potential source of selection bias because it fails to control for the possible differences in characteristics of participants (JCFs) and non-participants (NJFs) in the estimation of welfare benefit. If the assumption holds, the least-squares procedure overestimates the treatment effects (Greene, 2002). Furthermore, the absence of counterfactual observations presents another econometric problem of missing data mentioned by Smith and Todd (2005). This missing information emanates from the point that outcomes and counterfactuals cannot be observed simultaneously.

The potential outcome framework for casual inferences discussed by Rubin (1974) addresses the missing data problem. The framework is based on the assumption that both participants (JCFs) and non-participants (NJFs) have potential outcomes, meaning it models what would have been the result if the smallholders decided not to participate in growing energy crops. The potential outcomes model estimates the average treatment effect on the treated (participation) as the difference between the expected outcome from observed units and their counterfactual outcomes, denoted by $E(Y_{1i} - Y_{2i})$; where Y_{1i} is the observed unit and Y_{2i} is the counterfactual (Imbens & Wooldridge, 2009).

5.3.2 Empirical strategy

Sen (1981a) entitlement thesis pioneered the poverty classification to map vulnerability. A household's poverty can be assessed as an outcome of their capability, functioning, access to essential infrastructure and services used to earn a living. Absolute poverty captures the headcount of households unable to meet defined basic bundles of goods and services. Relative poverty measures the income gap to meet defined minimum welfare thresholds (e.g., poverty line). The Foster Greer Thorbecke (FGT) approach, which decomposes poverty into (i) incidence, (ii) gap, and (iii) severity of poverty, was used to compare poverty profiles between JCFs and NJFs. The FGT index is a commonly used technique in poverty assessments merited for its simplicity and decomposability (NSO, 2012; Sinyolo *et al.*, 2014a). The FGT indices were calculated using Stata 15 as below (equation 5.1).

$$P(\alpha) = \frac{1}{n} \sum_{i=1}^k \left\{ \frac{\theta - y_i}{\theta} \right\}^{\alpha} \quad (5.1)$$

Where $P(\alpha)$ is the poverty index, n is the number of sampled households, k is the number of households below the benchmark poverty line, θ is the calculated/adopted cut-off poverty line, y_i is the observed consumption expenditure per adult equivalent for the i -th household, and α is the aversion parameter taking the value of 0, 1, or 2. By varying the corresponding value of α the equation gives poverty incidence ($\alpha = 0$), also known as headcount index, poverty gap index ($\alpha = 1$) which shows the extent people fall below the poverty line and lastly, the poverty severity index ($\alpha = 2$) also known squared poverty gap index, P_2 .

This study also aimed at estimating the welfare impacts of *Jatropha curcas* cultivation through a *causal* relation. The lack of randomization in the placement of treatment units causes selection bias, and the decision to participate in *Jatropha curcas* cultivation can be potentially endogenous. The study used two complementary techniques, the endogenous switching regression (ESR) and propensity score matching (PSM), to account for endogeneity and self-selection bias.

The rationale behind PSM is to construct a statistical group of counterfactuals likely to participate in an intervention using observable characteristics. The technique uses binary regression to generate propensity scores on pre-treatment observable characteristics likely to influence participation. The propensity scores are used to identify observationally similar non-participants to match with the participant. The treatment effect is given by the difference in outcomes of interest between treated and counterfactual observations. The conditional independence assumption (CIA) assumes treatment does not affect outcomes, meaning that there are no unobserved factors affecting outcomes (Khandker *et al.*, 2010). Accordingly, the balancing property was employed to improve the quality of matches following several iterations. Block adjustments were made, and the common support condition was also imposed. The rationale was to ensure sufficient overlap and even distribution of observations within blocks between treatment and untreated units. The model was estimated using two different algorithms, propensity score matching (PSM) and nearest neighbour (NN) method, to test the consistency of the results in Stata 15. The major limitation of PSM is that it does not account for the unobserved characteristics. PSM also assumes the covariate effect (coefficients) to be the same between treatment and control groups, which is not necessarily the case from recent

studies (Negash & Swinnen, 2013; Shiferaw *et al.*, 2014; Khonje *et al.*, 2015). The unobserved factors in the propensity score estimation can generate mismatching and biased estimators (Heckman & Navarro-Lozano, 2004). Furthermore, the disadvantage of using one econometric technique is that estimates may be sensitive to the model assumption making the results not robust enough. Moreover, each model has its limitation (Shiferaw *et al.*, 2014; Khonje *et al.*, 2015). To remedy this problem, the endogenous switching regression was also used to account for selection bias from the unobservable covariate effect (Asfaw *et al.*, 2012a).

The ESR model accounts for selection bias and structural differences between the outcome functions of *Jatropha curcas* cultivating farmers and the non-*Jatropha* farmers. The ESR allows for covariate effects to vary across the two outcome functions and shows the extent of covariate influence (Di Falco *et al.*, 2011; Negash & Swinnen, 2013). Following Asfaw *et al.* (2012a), using notations, the model specification can be presented in two parts; the first part represents a binary choice H_i^* whether to cultivate *Jatropha* or not in the following form:

$$H_i^* = \alpha Z_i + \mu_i \text{ where } H_i = \begin{cases} 1 & \text{if } H_i^* > 0 \\ 0 & \text{if } H_i^* \leq 0 \end{cases} \quad (5.2)$$

That is, a smallholder will choose to participate in *Jatropha* cultivation ($H_i = 1$) if $H_i^* > 0$, or otherwise ($H_i = 0$) if $H_i^* \leq 0$. The latent variable H_i^* denoted the expected benefits from *Jatropha* cultivation, while Z_i represented a vector of determinants (household, farm characteristics, social factors) of the cultivation decision. The second part describes the continuous dependent function, which models outcomes. Let a farmer belonging to regime 1 (JCFs) or regime 2 (NJFs) be denoted by a binary latent variable H_i^* , taking the value of 1 when observed and 0 otherwise as defined below.

$$\text{Regime 1: } y_{1i} = X_{1i} \beta_1 + v_i \text{ (JCFs equation) } \quad \text{if } H_i = 1 \quad (5.3)$$

$$\text{Regime 2: } y_{2i} = X_{2i} \beta_2 + \omega_i \text{ (NJFs equation) } \quad \text{if } H_i = 0 \quad (5.4)$$

where y_{ji} are welfare functions (dependent variables). In this study, the proxy used to measure household welfare was household consumption expenditure per AEU (i.e. marketable and non-marketable goods and services) normalised by the square root of household size to allow for scale economies (Deaton, 1997; van de Walle, 2013). X_i and Z_i are vectors of regressors, and α, β_1, β_2 are vector parameter estimates. The variables μ_i, v_i , and ω_i are error terms assumed

to have a trivariate normal distribution with mean zero and covariance matrix Ω .

$$\Omega = \text{cov} (\mu_i, v_i, \omega_i) = \begin{bmatrix} \sigma_\mu^2 & \sigma_{\mu v} & \sigma_{\mu \omega} \\ \sigma_{\mu v} & \sigma_v^2 & \sigma_{v \omega} \\ \sigma_{\mu \omega} & \sigma_{\omega \mu} & \sigma_\omega^2 \end{bmatrix} \quad 5.5$$

Where σ_μ^2 is the error term for the selection equation (which can be assumed to equal to 1 since coefficients are estimable only up to a scalar factor); σ_v^2 and σ_ω^2 are variances for the error terms of outcome equations (5.3) and (5.4); $\sigma_{\mu v}$ and $\sigma_{\mu \omega}$ are the covariances of the selection equation and the two outcome equations which capture the direction and degree of non-random selection. Lastly, the covariances between the outcome equations v_i , and ω_i is undefined because y_{1i} and y_{2i} are never observed simultaneously (Maddala, 1983). It can be assumed that $\sigma_\mu^2 = 1$ since α is only estimable to the scalar factor. The model identification is by construction through nonlinearities. Given the assumption of the distribution of the disturbance terms, the logarithmic likelihood function for the system of equations (5.2) and (5.3 and 5.4) can be given as follows (Lokshin & Sajaia, 2004).

$$\begin{aligned} \ln L_i = & \sum_{i=1}^N H_i \left[\ln \phi \left(\frac{v_i}{\sigma_{\mu v}} \right) - \ln \sigma_{\mu v} + \ln \Phi(\varphi_{1i}) \right] \\ & + (1 - H_i) \left[\ln \phi \left(\frac{\omega_i}{\sigma_{\mu \omega}} \right) - \ln \sigma_{\mu \omega} + \ln(1 - \Phi)(\varphi_{2i}) \right] \end{aligned} \quad 5.6$$

Where $\varphi_{ji} = \frac{(Z_i \alpha + \rho_i \varepsilon_j / \sigma_j)}{\sqrt{1 - \rho_i^2}}$, $j_i = 1, 2$ with $\rho_1 = \sigma_{\mu v} / \sigma_\mu \sigma_v$ representing the correlation coefficient between the error term μ_i for selection equation (5.2) and the error term v_i and $\rho_2 = \sigma_{\mu \omega} / \sigma_\mu \sigma_\omega$, ε_j denotes the error terms for outcome equations (5.3) and (5.4), respectively. To ensure that estimates for ρ_1 and ρ_2 are within the bounds of -1 and 1 and σ_v and σ_ω are always positive the maximum likelihood procedure directly estimates $\ln \sigma_{\mu v}$ and $\ln \sigma_{\mu \omega}$ and $\text{atanh } \rho_j$ (Maddala, 1983; Lokshin & Sajaia, 2004). The expected values of v_i , and ω_i conditional on sample selection are non-zero because of the possible correlation of selection equation error term and the residues of the outcome equations (5.3) and (5.4) (Asfaw *et al.*, 2012b).

$$E(v_i | H_i = 1) = \sigma_{\mu\nu} \frac{\phi(Z_i\alpha)}{\Phi(Z_i\alpha)} = \sigma_{\mu\nu}\lambda_\nu \quad 5.7$$

$$E(\omega_i | H_i = 0) = \sigma_{\mu\omega} \frac{\phi(Z_i\alpha)}{1 - \Phi(Z_i\alpha)} = \sigma_{\mu\omega}\lambda_\omega \quad 5.8$$

Where $\phi(\cdot)$ is the standard normal probability density function, $\Phi(\cdot)$ is the standard normal cumulative density function, and their ratio evaluated at $Z_i\alpha$ gives the inverse mills ratios, $\lambda_\nu = \frac{\phi(Z_i\alpha)}{\Phi(Z_i\alpha)}$ and $\lambda_\omega = \frac{\phi(Z_i\alpha)}{1 - \Phi(Z_i\alpha)}$, where λ_ν and λ_ω are estimated from the selection equation (5.2), which is later included in equations (5.3) and (5.4), respectively, to correct for selection bias.

The full information maximum likelihood (FIML) approach efficiently estimates the binary choice and continuous outcome equations simultaneously (Maddala, 1983; Lokshin & Sajaia, 2004). The FIML method simultaneously estimates equations 5.2 to 5.4 (selection and outcome equations) to obtain consistent standard errors (Asfaw *et al.*, 2012b). The *movestay* command, written by Lokshin and Sajaia (2004), was used to run the model in Stata 15. Other than testing for endogeneity, the signs of the covariance terms $\sigma_{\mu\nu}$ and $\sigma_{\mu\omega}$ (the coefficients of λ_ν and λ_ω) have economic interpretation. When $\sigma_{\mu\nu}$ and $\sigma_{\mu\omega}$ have alternate signs, then smallholders chose to participate in *Jatropha* cultivation based on their comparative advantage; that is, those who decide to participate have above-average returns from participation while those who chose not to participate have above-average returns from non-participation. Conversely, if the Rho values are the same, it indicates ‘hierarchical sorting’; i.e., smallholders who decide to cultivate *Jatropha* have above-average returns whether they participate in *Jatropha* cultivation or not but are better off when they participate than not. Those who do not participate have below-average returns in either case but are better off not adopting. The parameters β_1 and β_2 in equation (5.3) and (5.4) measure the effect of *Jatropha* cultivation. They capture the marginal effect of the covariate on the choice of Y unconditional on the smallholders observed choice, which is the potential effect of the change in an independent variable on the sample (Fuglie & Bosch, 1995; Coulibaly *et al.*, 2017). In this model, holding a membership position in a social grouping (social) was added to the selection equation among factors that encourage participation in *Jatropha* cultivation but not consumption expenditure directly for model

identification (convergence) (Khonje *et al.*, 2015).

Conditional expectations, treatment, and heterogeneity effects

Following Di Falco *et al.* (2011) and (Asfaw *et al.*, 2012b), the endogenous switching regression model can also be used to calculate conditional expectations after obtaining the parameter estimates. Conditional expectations can be used to estimate the average treatment effect on the treated (ATT) and untreated (ATU) by making comparisons between the expected consumption expenditures between the observed and counterfactual outcomes for JCFs and NJFs as follows (see also Table 16): For the JCFs when participating in *Jatropha* cultivation (observed in the sample) can be given as:

$$E(y_{i1} | H_i = 1; X_i) = X_{i1} \beta_1 + \sigma_{\mu\nu} \lambda_{i\nu} \quad 5.9$$

The case of NJFs without participation in *Jatropha* cultivation (observed in the sample) can be given as below:

$$E(y_{i2} | H_i = 0; X_i) = X_{i2} \beta_2 + \sigma_{\mu\omega} \lambda_{i\omega} \quad 5.10$$

A counterfactual scenario for JCFs, if they decided not to cultivate *Jatropha*, is as follows:

$$E(y_{i2} | H_i = 1; X_i) = X_{i1} \beta_2 + \sigma_{\mu\omega} \lambda_{i\nu} \quad 5.11$$

Lastly, the case of NJFs, if they decided to cultivate *Jatropha*, is as given as follows (counterfactual):

$$E(y_{i1} | H_i = 0; X_i) = X_{i2} \beta_1 + \sigma_{\mu\nu} \lambda_{i\omega} \quad 5.12$$

The average treatment effect on the treated from the equations above is estimated as follows:

$$\begin{aligned} \text{ATT} &= (y_{i1} | H_i = 1; X_i) - (y_{i2} | H_i = 1; X_i), \\ &= X_{i1} (\beta_1 - \beta_2) + \lambda_{i\nu} (\sigma_{\mu\nu} - \sigma_{\mu\omega}) \end{aligned} \quad 5.13$$

Lastly, the mean treatment effect on the untreated is estimated as denoted below:

$$\begin{aligned} \text{ATU} &= (y_{i1} | H_i = 0; X_i) - (y_{i2} | H_i = 0; X_i), \\ &= X_{i2} (\beta_1 - \beta_2) + \lambda_{i\omega} (\sigma_{\mu\nu} - \sigma_{\mu\omega}) \end{aligned} \quad 5.14$$

The diagonal scenarios (i) and (iv) in Table 16 denoted the actual expectations, while (ii) and

(iii) are the counterfactuals. The expected change in mean outcomes for JCFs or NJFs if they had similar characteristics to each other is captured by the right-hand side of equations (5.13) and (5.14). The lambda (λ_i) is the selection term which accounts for all potential differences in unobservable covariate effects (Khonje *et al.*, 2015). The ATT can be estimated as the difference between the expected consumption expenditures of JCF and their counterfactual outcomes (if they did not cultivate *Jatropha*) [i.e., (v) in Table 16]. Similarly, ATU can be estimated by comparing the expected consumption expenditure of NJFs to the outcomes in the hypothetical counterfactual scenario (if the cultivated *Jatropha*) [i.e., (vi) in Table 16].

The base heterogeneity effect for the treated (JCFs) sample (BH_1) is estimated as the difference between the observed average expected consumption expenditures and the counterfactual outcome of the untreated group (NJFs). Similarly, for the untreated (NJFs) sample (BH_2), the mean difference in observed expected consumption expenditures for NJFs and the counterfactual outcome for JCFs gives the base heterogeneity effect. Base heterogeneity captures unobservable characteristics (e.g. attitude to work, entrepreneurial spirit), separating JCFs from NJFs even before adopting the crop (Di Falco *et al.*, 2011; Fitawek & Hendriks, 2021). Lastly, transitional heterogeneity can be estimated as the difference between ATT and ATU. Transitional heterogeneity indicates whether the effect of *Jatropha* cultivation was large or small for smallholders who cultivated *Jatropha* or for NJFs in the counterfactual scenario that they decided to cultivate *Jatropha* (Asfaw *et al.*, 2012b).

Table 16 Conditional expectations, treatment, and heterogeneity effects

Category	Decision phase		Treatment effect			
	To grow		Not to grow			
JCFs	(i)	$E(y_{i1} H_i = 1)$	(ii)	$E(y_{i2} H_i = 1)$	(v)	ATT
NJFs	(iii)	$E(y_{i1} H_i = 0)$	(iv)	$E(y_{i2} H_i = 0)$	(vi)	ATU
Heterogeneity effect		BH ₁		BH ₂		TH

Notes: NJFs = Non-*Jatropha* farmers, JCFs = *Jatropha* cultivating farmers. (i) and (iv) represent the observed expected consumption expenditure per AEU. (ii) and (iii) represent the counterfactual expected consumption expenditure per AEU. $H_i = 1$ if smallholder participated in *Jatropha* cultivation while $H_i = 0$ if the household did not cultivate *Jatropha*. y_{i1} = consumption expenditure per AEU if household participated in *Jatropha* cultivation. y_{i2} = consumption expenditure per AEU if household did not participate in *Jatropha* cultivation. ATT = average treatment effect on the treated while ATU = average treatment effect on the untreated. BH_i = Base heterogeneity for JCFs [$i = 1$, i.e. (i - iii)] and NJFs [$i = 0$, i.e. (ii - iv)]. TH = transitional heterogeneity [TH=ATT-ATU, i.e. (v-vi)].

Source: Adapted from Asfaw *et al.* (2012b).

Since the ESR estimates may be sensitive to the model's assumption, selection bias was also modelled as a function of observable characteristics to test the robustness of the results (Shiferaw *et al.*, 2014; Herrmann *et al.*, 2017; Ahimbisibwe *et al.*, 2020). PSM uses the probability of participating in an intervention using observable characteristics to construct a counterfactual group to compare outcomes (Heckman *et al.*, 1998). Propensity scores generated from probit or logit models are used to match the treated households (JCFs) with the untreated units (NJFs). The mean difference in outcomes between treated units (JCFs denoted $Y_{1i} = 1$) and 'similar' untreated group (NJFs denoted $Y_{2i} = 0$) is the estimated average treatment effect on the treated ($Y_{1i} - Y_{2i}$) (Wooldridge, 2002).

5.3.3 Definition of variables

The dependent variable used as the welfare measure in this study was consumption expenditure per adult equivalent. Consumption expenditure was calculated as an aggregate of total household expenditure, including monetized domestic food production.

The independent variables considered in this study are presented in Table 17. The household demographic and household characteristics included gender, farming experience, domestic

labour, and education endowment. A previous study suggests (in the study area) that male-headed households have more earning opportunities (usually male-dominated activities such as fishing), implying that female-headed households are likely to have lower consumption expenditure (Katengeza et al., 2012). Farming experience is associated with the smallholders' age; as such older farmers are likely to have better networks, knowledge of risks, and opportunities in agriculture production. However, older farmers are also known to be risk-averse, and more appreciative of traditional functions and preferences. Consequently, they are likely to be more concerned with production sustainability, which is negatively associated with innovations' uptake. The hypothesized influence of farming experience was ambiguous *a priori* (Qualls et al., 2012; Kuntashula et al., 2014; Kidane & Wale Zegeye, 2019). Households with more members in the working-age groups have higher domestic labour endowments; therefore, labour availability was expected to positively influence welfare. More years of formal education are associated with better quality labour and higher marginal labour productivity, which may entail better-paying jobs. Furthermore, more years of education implies a better understanding of innovations and adoption of improved agricultural practices (Bogale, 2012; Sinyolo et al., 2014a). Education endowment was expected to positively influence welfare.

Landholdings, livestock ownership, agricultural equipment index, durable asset index and soil fertility were endowment factors used in the study. Higher land holdings present opportunities for expanding existing or diversifying production to exploit current and future potential agricultural opportunities (Mendola & Simtowe, 2015). Therefore, landholdings was expected to positively influence welfare.

Table 17 Definition of variables used in welfare impacts assessment

Variable	Description	Type	Sign
Log farming experience	Natural log of farming experience	Continuous	+/-
Effective labour ²⁹	Labour availability in man-equivalent units	Continuous	+
Household asset index ³⁰	Pc- durable household assets	Continuous	+
Land (ha)	Landholdings (Ha)	Continuous	+
Agric. equip index ³¹	Pc- agriculture equipment holdings	Continuous	+
Total livestock units	Livestock units are calculated based on 250kgs liveweight regardless of type	Continuous	+
Gender	Gender of the household head (Male = 1, 0 otherwise)	Dummy	+
Education endowment	Average schooling years for all members	Continuous	+
Off-farm income	Access to off-farm income (1 = Yes, 0 = No)	Continuous	+
Soil fertility status	Soil fertility status (1= fertile, 0 = otherwise)	Dummy	+
Access to extension	Access to agricultural extension services (1=Yes, 0 = No)	Dummy	+
Public phones	Distance to nearest public phones (minutes)	Continuous	-
Access to credit	Access to credit (1 = Yes, 0 = No)	Dummy	+

Source: Own Survey, 2014.

²⁹ Effective household labour availability in man-equivalent units was calculated as follows : children < 9 years = 0, 9 to 15 years = 0.7, 16 to 49 years =1 and > 49= 0.7 (Runge-Metzger, 1988 cited in Kuntashula & Mungatana, 2013). Due to data availability, these units were further modified to account for the working status on the farm for all family members as follows: full time = 1 and part-time = 0.5.

³⁰ The household asset index was constructed using principal component analysis. All household assets were first categorised as dummies to indicate whether a household possessed the assets or not. The following items were included in this analysis: radio, bicycles, mats/mattress, bed, blankets, sofa, table, chairs, television, and cell-phone.

³¹ The agriculture equipment index was constructed similarly to the above. The items included in the analysis were as follows: plough, sprayer, irrigation can, granary, treadle pump, ox-cart, hand hoe and *panga* knife.

The durable asset index represents the household's long-term wealth status (Chirwa *et al.*, 2017). Wealthier smallholders can afford expensive inputs and hire labour to increase production. A higher asset index was expected to be associated with better welfare. Compared to individual farm tools, the agricultural equipment index measures aggregate farm productivity (Günther & Harttgen, 2009). Agricultural equipment increases the efficiency of farming operations and the quality of outputs. The agricultural equipment index was expected to be positively associated with welfare.

Livestock sales during lean seasons provide essential means for smoothing consumption. Furthermore, organic manure from livestock improves soil quality and yields (Mogaka *et al.*, 2010; Lopez-Ridaura *et al.*, 2018). Total livestock units were expected to positively influence welfare. Soil fertility was used as a measure of land quality. Smallholders owning fertile plots would likely require relatively less added inputs to get a good crop, thereby reducing production costs (Bogale, 2012). Soil fertility was expected to positively influence welfare.

Access to services variables included access to credit, off-farm income, and public phones. Agricultural extension services are essential in promoting smallholder productivity by disseminating innovations and managing pests and diseases (McCord *et al.*, 2015; Kidane & Wale Zegeye, 2019). Access to extension services was hypothesised to positively influence welfare. Access to off-farm incomes provides additional cash streams to the household, which can be used for consumption or invested in agricultural inputs (Asmah, 2011). Access to off-farm income was expected to positively influence welfare. Lastly, public-phone was used as a proxy for the remoteness of an area. Distance to markets can be used as a proxy for transactional costs (Asfaw *et al.*, 2012b). Smallholders located closer to trading centres enjoy lower transactional costs in accessing inputs and output markets than those from remote areas. Previous studies have also shown that farmers situated further away from public services (such as markets, roads) are more inclined to preserving local traits and production sustainability, which generally yield less than improved varieties (Wale, 2010). Furthermore, remoteness limits opportunities for better paying off-farm incomes (Tembo *et al.*, 2009). The variable Public phones was expected to negatively influence welfare. Lastly, access to agricultural extension services was hypothesized to influence participation in *Jatropha* cultivation but not directly affect consumption expenditure (Khonje *et al.*, 2015).

5.4 Results

5.4.1 Descriptive statistics

Table 18 presents basic summary statistics of smallholders on household demographics and other socioeconomic characteristics. The average age for the smallholders was 45.6 years, and most households were male-headed. The average landholdings size was 1.3 hectares. Key informant interviews revealed that most of the land in the study areas fall under customary land tenure, and ownership was passed on through a matrilineal inheritance system. Farming was a primary occupation in most rural areas, though some significant differences were observed between JCFs (87%) and NJFs (93%). In places where *Jatropha curcas* was cultivated, the fishing value-chain was ranked as the most important livelihood strategy. However, the distribution of the proceeds from fishing activities was likely to favour male-headed households (72%). Gender participation and roles showed that most activities (primary fishing, pulling nets, rope making) were male-dominated except for small scale fish trading, which was ranked as least important (Appendix A. 5). Conversely, NJFs considered farming (rainfed agriculture) and winter season wetland cultivation as their most essential livelihood strategies.

Table 18 Means of household socioeconomic variables for JCFs and NJFs (n = 298)

Variables	All Sample	JCFs (n=96)	NJFs (n=202)	t-test (chi ²)
<i>Household demographics</i>				
Age (years)	45.6	47.7	44.6	1.61
Gender of HH head (1 = male)	0.72	0.74	0.71	0.23
Household size	5.87	5.85	5.88	0.12
Household size in adult equivalents ³²	4.3	4.5	4.4	0.98
Effective household labour (adjusted man-equivalent units)	2.49	2.4	2.5	0.57
Primary occupation (1 = farmer)	0.91	0.87	0.93	3.40*
Farming experience (years)	27	28.3	26.4	0.98
Mean household education endowment	3.8	3.6	3.9	1.5
Membership position in social group (1=Yes)	0.34	0.25	0.38	4.65*
Access to off-farm income (1 = Yes)	0.51	0.53	0.5	0.25

³² Household size was adjusted for age and gender (Ligon & Schechter, 2003).

Variables	All Sample	JCFs (n=96)	NJFs (n=202)	t-test (chi ²)
<i>Household wealth and farm variables</i>				
Landholding size (ha)	1.3	1.3	1.4	0.4
Soil fertility status (1= fertile)	0.27	0.29	0.26	0.39
Tropical Livestock Units	0.81	1.5	0.47	2.82**
Household Asset index	0.0013	-0.29	0.13	2.41*
Agric. equipment access index	0.0005	-0.38	0.18	3.25**
<i>Output and Outcome variables</i>				
Consumption expenditure/AEU (,000 Mwk) ³³	90.3	80	95.3	2.73**
Crop sales income (,000 Mwk)	46.6	32.5	53.3	1.9*
Livestock sales income (,000 Mwk)	11.7	13.3	11.1	0.66
Off-farm income (,000 Mwk)	88.8	71.4	97.1	1.28
Level of food production (1= enough)	0.12	0.24	0.37	5.11*
<i>Access to services and amenities</i>				
Public phone (distance in minutes)	11.3	13.8	10.0	2.45*
Extension access (1 = Yes)	0.7	0.55	0.77	14.3***
Credit access (1 = Yes)	0.25	0.11	0.32	1.1

Notes: NJFs = non-*Jatropha* farmers, JCFs = *Jatropha* cultivating farmers. The test statistics are absolute values, t-tests for continuous variables and chi-square tests for nominal or categorical variables: *significant at $\rho < 0.1$, ** significant at $\rho < 0.05$ and ***significant at $\rho < 0.01$

Source: Own survey (2014).

The household asset index showed that JCFs had significantly fewer durable assets compared to NJFs. Similarly, JCFs had significantly less access to agriculture equipment compared to NJFs. However, *Jatropha curcas* cultivating farmers owned significantly more livestock, measured in tropical livestock units³⁴ (1.5) than NJFs (0.47).

³³ 1US\$ = MwK390 (July 2014)

³⁴Tropical livestock units (TLUs) is a widely used index for livestock owned which is based on body weight regardless of species compared to a unit reference of a 250kg animal

Regarding access to public facilities and other services, there were large variations in reported access to extension and nearest trading centres. While slightly over half of the JCFs (55%) had access to extension services, a significantly large number of NJFs (77%) had contacted an agricultural extension agent in the year of the study. Public phones were used as proxies for the remoteness of the area. JCFs were significantly further away from trading centres where households could access essential services such as input and output markets.

Jatropha curcas cultivating farmers received significantly less income from crop sales by an average of almost 60% compared to NJFs. Discussions with farmers described the following as constraints to agricultural production: unaffordable prices of inorganic fertilisers, challenges in accessing government-subsidized fertiliser (FISP), climate variability, high cost of chemicals for crop protection (e.g., beetles in *Jatropha curcas*) and low farmgate prices.

Furthermore, the market for *Jatropha curcas* is not well developed in Malawi (Mponela *et al.*, 2011). *Jatropha curcas* cultivating farmers decried lack of competition as another setback since BERL was the only buyer of *Jatropha curcas* seeds. To address some of the market-related challenges, smallholders suggested engaging in pre-season interphase negotiations with potential buyers to attain (i) improved farm gate prices for *Jatropha* in the following seasons and (ii) improved commitment to strengthening marketing systems with more buyers.

The perceived level of food production was also lower for JCFs as compared to NJFs. The results showed that a significantly smaller percentage (24%) of JCFs rated their food production as generally enough. Overall, *Jatropha curcas* cultivation was associated with large variations in household welfare measured as consumption expenditure per AEU. The welfare of JCFs was significantly lower by almost 20 percentage points compared to NJFs. While these results need to be interpreted with caution, competition for resources (family labour and purchased inputs), which might have been diverted away from agricultural production, could be another possible explanation for the low domestic food production.

5.4.1.1 Foster Greer Poverty index analysis

Table 19 compares levels of absolute (headcount) and relative poverty (gap ratio) using FGT indices between JCFs and NJFs. The FGT indices provide a glance at the welfare differences between JCFs and NJFs. For purposes of this study, a relevant local poverty line threshold measured in Malawi Kwachas developed by The National Statistical Office (NSO) was adopted

and adjusted for inflation to K65,554 per adult equivalent per year (NSO, 2012). As a robustness test, another higher threshold pegged at 10% above the poverty line value was also used to conduct a sensitivity test (Deaton, 1997).

Table 19 Foster Greer Thorbecke (FGT) Poverty indices results showing the percentage of households under different poverty measures (n = 298)

Parameter	JCFs	NJFs	Difference
<i>Headcount ratio (%)</i>			
Poverty line	40.6	26.7	13.9
Poverty line (+10%)	44.8	34.7	10.1
<i>Poverty gap ratio %</i>			
Poverty line	11.7	8.1	3.6
Poverty line (+10%)	14.7	10.2	4.5
<i>Squared poverty gap ratio</i>			
Poverty line	5.5	3.9	1.6
Poverty line (+10%)	6.9	4.8	2.1

Notes: NJFs = non *Jatropha* farmers, JCFs = *Jatropha* cultivating farmers.

Source: Own survey, 2014.

Poverty incidence results reported in Table 19 suggest that 40% of JCFs were categorised as poor, about 14 percentage points more than the NJFs. Similarly, the poverty gap ratio (11.7%) and severity of poverty were also higher for JCFs than their counterparts. The poverty gap result suggests that consumption expenditure for JCFs needed to rise by close to 12% to reach the cut-off poverty line compared to 8% for NJFs. The sensitivity analysis simulated at a higher poverty line (10% above the poverty line) also showed a similar trend with more JCFs falling below the poverty line.

The comparative assessment suggests that absolute and relative poverty were more widespread among JCFs compared to NJFs. A possible explanation can be found by scrutinising the outcomes of the livelihood strategies of the two groups. Table 18 showed that JCFs produced significantly less food and received less income from crop sales than NJFs. While most of the JCFs considered farming as their primary occupation (87%), the ranking of fishing activities ahead of farming during the focus group discussion underscores the relative importance of the

fishing industry in their livelihoods (Appendix A. 5). Fishing and the earnings from the activities thereof were spread-out almost throughout the year, except for the closed seasons when fish breed (November to March), which could explain the perceived higher ranking over rainfed agriculture.

Nonetheless, these results suggest that the net benefits from these activities were comparatively lower relative to NJFs livelihoods. These results differ from Mudombi *et al.* (2016), who did not find any variations using multidimensional poverty indices between *Jatropha curcas* farmers and the untreated group. The multidimensional indices approach used a broader scope, which included access to safe drinking water, sanitation, electricity, and human capital development indicators like the level of education, among others. It has also been indicated that this approach hinged on long-term asset accumulation. Therefore, it would be more suitable for investments that were established over a relatively more extended period (e.g., sugarcane plantations) rather than the recently established *Jatropha* projects.

5.4.2 Determinants of household welfare impacts of *Jatropha* cultivation

Table 20 presents the ESR model results estimated using the full information maximum likelihood method with robust standard errors clustered at EPA level³⁵ following Di Falco *et al.* (2011) and Coulibaly *et al.* (2017), which accounts for unobserved selection bias. The dependent outcome variable used to measure welfare was consumption expenditure per AEU. The first column presents OLS estimates with no switching, shared for comparison purposes. The second column shows estimates of the selection equation, while columns three and four present the outcome models for JCFs and NJFs, respectively (i.e., equation 5.3 and 5.4). Table 20 presents the estimated coefficients of covariates, their significance levels, and the extent to which they influenced welfare. The correlation coefficients (Rho_1 and Rho_2) between the selection and outcome equations were both not significantly different from zero and had a negative sign. The insignificant correlation coefficients imply that the hypothesis of absence of selection bias may not be rejected, which could not be established *a priori* (Di Falco *et al.*, 2011). The signs of the correlation coefficients indicate ‘hierarchical sorting’, suggesting that smallholders are better off in their observed regime choices; that is, JCFs are better off

³⁵ The `movestay` command was used to estimate the endogenous switching regression model in STATA 15 by FIML (Lokshin & Sajaia, 2004).

participating in *Jatropha* cultivation than not, while NJFs are also well-off not cultivating *Jatropha* (Fuglie & Bosch, 1995). The significance of the Wald Chi-square test rejects the hypothesis that the three equations are independent and confirms their joint dependence [selection (5.2) and outcome equations (5.3 and 5.4)]. Consistent with the model specification, the separate outcome equations rather than one, were justified as applied in the ESR model, which assumed that the covariate effects between the regimes are significantly different (see Table 20) (Ahimbisibwe *et al.*, 2020).

Almost all covariates (five) but one that significantly influenced welfare among JCFs had the expected positive sign. These included: wealth (assets), agriculture equipment access, land, gender, and soil fertility had positive signs while education endowment was negative. The significant covariates in the NJFs equation also had the expected positive signs except for gender, while farming experience was ambiguous *a priori*. Wealth (assets), land, agriculture equipment access, credit access, and public phones were the significant factors.

Table 20 Full information maximum likelihood estimates of the switching regression model.

Variable	OLS	Selection	JCFs model	NJFs model
	Coef.	Coef.	Coef.	Coef.
Jatropha cultivation	-8,688* (4,673)	--	--	--
Log farming experience	-5,140 (3,115)	0.045* (0.03)	2,538 (2,408)	-12,729*** (2,980)
Effective labour	1,465 (2,921)	-0.01 (0.09)	1,917 (1,431)	2,252 (2,471)
Household asset index	8,837*** (1,839)	-0.16 (0.11)	8,988*** (1,111)	11,280* (5,490)
Land (ha)	10,864** (3,739)	-0.12 (0.07)	7,327*** (1,222)	13,334*** (3,174)
Agric. equip index	4,037* (1,866)	-0.15* (0.07)	6,305*** (963)	6,405* (3,242)
Total livestock units	770 (738)	0.19* (0.10)	-166 (326)	5,886 (4,405)

Gender	-9,621 (7,344)	0.42 (0.28)	13,061*** (2,967)	-27,073* (12,093)
Education endowment	-2,010 (5,398)	0.08 (0.27)	-5,480* (2,348)	-4,059 (8,115)
Off-farm income	3,083 (4,658)	0.17 (0.31)	11,446 (8,980)	-5,680 (11,698)
Soil fertility status	4,925 (5,792)	-0.032 (0.18)	7,582* (3,470)	2,189 (5,180)
Public phones	-76 (201)	0.014** (0.004)	116 (94)	-577** (186)
Access to credit	9,960* (5,398)	-0.24* (0.14)	3,086 (3,221)	16,915* (8,908)
Access to extension	--	-0.39* (0.16)	--	--
Constant	98,309*** (18,974)	-1.01 (0.87)	65,672*** (18,375)	117,648*** (20,274)
Sigma			30,512 (1,353)	52,803 (10,137)
Rho			-0.23	-0.93
F-Test	6.63***			
n				298

Notes: Wald test of indep. equations $\chi^2(1) = 5.69$ (*). Robust standard errors clustered at EPA level in the parenthesis (Di Falco *et al.*, 2011; Coulibaly *et al.*, 2017). NJFs = Non-*Jatropha* farmers, JCFs = *Jatropha* cultivating farmers. The significance levels: * ($p < 0.1$), ** ($p < 0.05$) and *** ($p < 0.01$).

Source: Own survey, 2014.

The FIML switching regression estimates showed that the covariate effects were heterogeneous between JCFs and NJFs. Land availability defines the household's production frontier to expand existing activities or diversify into other enterprises. Landholdings had a positive and significant effect on the welfare of both farmer categories. However, the coefficient estimates in showed that relative to NJFs, JCFs were likely to benefit less for every additional hectare of land. Relative to JCFs, the NJFs group earned substantially more income from crop sales, which probably suggests that they enjoyed higher productivity since land and domestic labour endowments were not significantly different between the two groups. Focus group discussions

also revealed that farming (rainfed and wetland) was ranked the most important livelihood strategy for NJFs. Winter season cultivation was also a vital livelihood activity which suggests that NJFs spent more time on agricultural activities per year while JCFs ranked it second to fishing. Based on prior recommendations, *Jatropha curcas* was planted mostly in hedgerows around farmers' fields and marginal lands. While other studies suggest adequate land is vital for the intensification of a technology (Soto *et al.*, 2015), this may not necessarily always be the case for *Jatropha curcas* based on the planting recommendations stated above. Nonetheless, another study in Malawi found that land size positively influenced both the adoption and extent of *Jatropha curcas* cultivation (Mapemba *et al.*, 2013).

Access to off-farm income was significantly associated with the probability of higher welfare for JCFs only. Off-farm earning opportunities offer a diversified income base to smallholders mostly used to augment household incomes and expenditure gaps. These results are consistent with previous studies, which found that off-farm earning opportunities were positively associated with higher welfare in Ghana, Ethiopia, and Tanzania (Asmah, 2011; Asfaw *et al.*, 2012b). The high opportunity cost of labour potentially limits labour availability in agricultural activities (Katengeza *et al.*, 2012). However, the overall poverty profile result (Table 19) suggests that earnings in the fishing value-chain and other off-farm earning activities practised by JCFs were not very lucrative. Grass and Zeller (2011) reported a similar finding in Madagascar, where households with higher labour opportunity cost (running own businesses, etc.) were unlikely to offer their labour in *Jatropha curcas* plantations.

Gender of the household head (being male) was significantly associated with welfare but returned a positive sign for JCFs and negative for NJFs. The landholdings and level of input use (fertilisers) for JCFs were slightly higher for male-headed smallholders but not statistically significant from female-headed farmers except for the agricultural equipment index. Furthermore, the results indicate that male-headed households received significantly more agricultural income as compared to female-headed households ($p < 0.1$) (Appendix A. 6). The agricultural equipment index measures aggregate farm productivity (Günther & Harttgen, 2009). These results suggest that male-headed households might have enjoyed higher agricultural productivity as compared to female-headed households. Moreover, the Mangochi District has a wide diversity of livelihood options, including primary fishing, pulling fishnets, small scale trading, and wage employment (Appendix A. 5). Another possible explanation for the positive influence of gender could be that the fishing activities, which ranked as the most

important livelihood strategy among JCFs, are predominantly male-dominated. Unlike primary agricultural activities (rainfed), fishing activities run almost throughout the year except for closed seasons (November and March) when fishing is restricted. The proceeds from fishing economic activities that span for a relatively more extended period in the year compared to rainfed agriculture are likely to be skewed towards male-headed households. Consistent with the above, further investigation also showed that, on average, male-headed households received significantly more off-farm income as compared to female-headed smallholders ($p < 0.1$) (Appendix A. 6). These results are consistent with a study in Ethiopia that found that male-headed households tend to have stable incomes and are not vulnerable to expected poverty. The study suggested that limited access to assets and services constrains the welfare of women (Kidane & Wale Zegeye, 2019).

On the other hand, the negative sign on gender variable for NJFs was not expected, and the reasons behind the effect were not obvious. Nonetheless, cross-tabulation results indicated that, on average, female-headed households received slightly more agricultural income. There were also more female-headed households (23%), who perceived their level of food production as adequate compared to male-headed households (14%) (Appendix A. 6).

Education endowment was significantly associated with welfare for JCFs only but returned a negative sign. The negative sign on education endowment was not expected, and the reasons behind the effects were also not obvious. Although further investigations would be necessary to clearly understand the negative relationship with welfare, a possible explanation would be the limited earning opportunities in rural areas. While education is associated with interpreting, experimenting, and adopting innovation, these results suggest that gains from human capital development may be dismal without economic opportunities. Kidane and Wale Zegeye (2019) also found that higher educational endowment was correlated to income variability in Ethiopia. The study suggests that the skills and knowledge attained through years of schooling were inadequate to nurture entrepreneurial proficiencies to take up opportunities, create jobs, and improve welfare.

Access to agricultural equipment was positive and significantly associated with higher welfare for JCFs and NJFs. These results also suggest that JCFs and NJFs would benefit by almost the similar magnitudes from increased access to productive assets. Agricultural equipment, such as sprayers and ploughs, is essential to improve crop protection, productivity, and labour

efficiency, which increase productivity, yields, and eventually farm revenues. Descriptive statistics showed that JCFs had significantly lower access to agricultural equipment than NJFs (see Table 18). The relative importance of their livelihood strategies might explain this result (see Appendix A. 5). Depending on their perceived importance, competition between livelihood activities may divert scarce resources from investment in farming equipment into other tools (e.g., fishing gear).

Household durable assets, a proxy for household wealth status, were significantly and positively associated with higher welfare for JCFs and NJFs. While wealthier households may have more resources for investment in agricultural innovations, the relatively low levels of equipment and management required for *Jatropha curcas* production, processing and marketing enable even resource-poor smallholders to participate as feedstock producers. The findings are supported by Mujeyi (2009), who also reported that *Jatropha* required less technology and management to produce and market, which may not necessarily appeal to high-end wealthier farmers.

The perceived soil fertility of plots (a proxy for land quality) was significantly associated with higher welfare for JCFs only. Other results show that significantly more JCFs who perceived their land as fertile ($p < 0.1$) described their domestic level of food production as adequate compared to their counterparts. Smallholders who described their land as fertile also received significantly more agricultural income as compared to their counterparts. Further investigations showed that the variations in landholdings and level of input use (fertiliser consumption) between smallholders who considered their land as fertile (60.7 kgs ha^{-1}) and their counterparts (90.5 kgs ha^{-1}) were not statistically significant for JCFs (Appendix A. 6). These results suggest that smallholders with better land quality enjoyed higher agricultural productivity, reflected in better agricultural incomes. Poor soil fertility is one of the major constraints to increasing food production in SSA. Small landholdings entails that traditional soil fertility restoration measures are impractical for many smallholders. Consequently, added inputs are essential to increase yields on land with poor soil fertility (Manda *et al.*, 2017; Tefera *et al.*, 2017). As regards *Jatropha* cultivation, while the crop has mostly been promoted as suitable for marginal soils (Francis *et al.*, 2005), others have questioned if *Jatropha* can produce ecological and socio-economic benefits (yields) in the unfertile soils (Achten *et al.*, 2008). Other studies also suggest that *Jatropha curcas* performs better in good fertile soils, potentially increasing yields and proceeds from investment (Mogaka *et al.*, 2010; Shinoj *et al.*, 2010).

5.4.3 Impact of participation in *Jatropha* cultivation

5.4.3.1 Welfare impacts of *Jatropha* cultivation using ESR and PSM

The observed average outcome differences in consumption expenditure per AEU for the JCFs were almost 20% lower than NJFs. This simple comparison can be misleading as not all factors that defined consumption expenditure were known. Conditional expected outcomes account for the systemic variations, which could not be addressed solely by observable characteristics as determinants of welfare.

The results from conditional outcome expectations used to assess the base and transitional heterogeneity are presented in Table 21. The treatment effect in the last column of Table 21 represents the expected consumption expenditure per AEU for a randomly drawn household in their respective groups and smallholder's typology. The results show that participation was associated with an average increase of 11% in consumption expenditure per AEU (8,569.9 Kwachas). However, the effect was not statistically significant. While it can be argued that most hedges had not yet reached full maturity and expected yield potential at the time of the study, *Jatropha* was primarily promoted as a developmental crop characterised by indigenous germplasm (Brittaine & Litaladio, 2010; van Eijck *et al.*, 2012). Focus group discussions with farmers also highlighted other market-related challenges affecting demand and prices. Mponela *et al.* (2011) also reported that markets for *Jatropha curcas* were not well-developed in Malawi. A recent study from Zambia cited lack of markets and non-profitability as major reasons farmers abandoned *Jatropha* cultivation (Kunda-Wamuwi *et al.*, 2017). The findings are also consistent with previous studies, which suggested that so far, JCFs had received insufficient incomes from feedstock sales to impact on poverty reduction, and participation in growing energy crops may not necessarily deliver human wellbeing outcomes (Mudombi *et al.*, 2016; Ahmed *et al.*, 2019).

Table 21 Average expected consumption expenditure per AEU for the decision to grow or not to grow *Jatropha* (Kwachas) and typology

Category/ Typology	n		Decision Phase				Average treatment effect
			To participate		Not to participate		
JCFs	96	(a)	79,995 (2,523)	(c)	71,543 (5,227)	(e)	8,452
NJFs	202	(b)	31,189 (1,672)	(d)	96,434 (1,684)	(f)	-65,245***
		BH1=	48,806	BH2=	-24,891	TH=	73,696
<i>Type I (Agric. labourers)</i>							
JCFs	25	(a)	81,028 (3320)	(c)	59,726 (5,912)	(e)	21,303**
NJFs	38	(b)	29,330 (3,281)	(d)	86,251 (2,733)	(f)	-56,921***
		BH1=	51,699	BH2=	-26,525	TH=	78,224
<i>Type II (older uneducated farmers)</i>							
JCFs	22	(a)	72,450 (3,797)	(c)	51,919 (4,716)	(e)	20,531**
NJFs	22	(b)	29,837 (5,240)	(d)	87,196 (5,360)	(f)	-57,359***
		BH1=	42,613	BH2=	-35,277	TH=	77,890
<i>Type III (subsistence farmers)</i>							
JCFs	19	(a)	53,099 (3,715)	(c)	49,942 (5,617)	(e)	3,156
NJFs	37	(b)	3,838 (2,536)	(d)	79,215 (3,123)	(f)	-75,377***
		BH1=	49,261	BH2=	-29,273	TH=	78,533
<i>Type IV (Briefcase farmers)</i>							
JCFs	20	(a)	99,492 (3,089)	(c)	86,814 (5,829)	(e)	12,678*
NJFs	65	(b)	43,111 (2,000)	(d)	105,457 (2,675)	(f)	-62,346***

Category/ Typology	n	Decision Phase			Average treatment effect
		To participate		Not to participate	
		BH1= 56,381	BH2= -18,643	TH= 75,024	
Type V (<i>commercial farmers</i>)					
JCFs	8	(a) 115,332 (7,565)	(c) 179,658 (7,565)	(e) -64,326	
NJFs	37	(b) 39,213 (3,887)	(d) 112,983 (3,287)	(f) -73,770***	
		BH1= 76,119	BH2= 66,675	TH= 9,444	

Notes: NJFs = Non- *Jatropha* farmers, JCFs = *Jatropha* cultivating farmers. Using notations, base heterogeneity (BH) was calculated as (a - b) and (c - d), while transitional heterogeneity (TH) is (e-f). Standard errors are in parentheses.

Source: Own survey, 2014.

On the other hand, the expected outcome for the counterfactual scenario for NJFs showed large variations to the observed welfare. The results showed that consumption expenditure for NJFs would significantly decline if they had decided to grow *Jatropha curcas* (-65,280 Kwachas). NJFs were better-off in their choice of livelihood activities which earned them better welfare than if they decided to grow *Jatropha*. Moreover, the descriptive statistics (Table 18) showed that NJFs earned more income from crop sales than JCFs, suggesting that additional income flows from *Jatropha curcas* cultivation were insufficient to boost their expenditure. Comparatively, the proportionate change in the expected effect of *Jatropha* cultivation was significantly larger for NJFs relative to JCFs, which explains the positive transitory heterogeneity effect (Asfaw *et al.*, 2012b).

Following Coulibaly *et al.* (2017), the study also investigated the differential welfare outcomes among the different smallholders' typologies. Mean conditional expectations were analysed for the five smallholder clusters developed in Chapter 3. Table 21 showed significant differences in welfare outcomes in three of the five typologies for JCFs. The results suggest 'older uneducated smallholders' consumption expenditure would rise by 39.5%, followed by 'agricultural labourers' (35%) and 'briefcase farmers' (15%) if they decide to cultivate *Jatropha*. Table 6 showed that the first two clusters represented smallholders' with relatively low inputs use, the overall agricultural productivity of the household (agricultural equipment

index) and crop diversity. Unlike other crops, *Jatropha curcas* cultivation does not require high capital outlays, which might explain the positive welfare outcomes for the ‘agricultural labourers’ and ‘older uneducated smallholders’. These results are consistent with a previous study in Zimbabwe, which suggests that the level of management, equipment, and technical know-how required to participate in *Jatropha* cultivation is low, allowing resource-poor smallholders to enter the market (Mujeyi, 2009). Given these positive results, it is worthwhile highlighting the work of Harris and Orr (2014), which contends that the magnitudes of gains from agricultural innovations are too small to make a meaningful impact because of limited land and market access. Lack of an established market for *Jatropha* and a limited number of buyers were cited as important constraints in focus group discussions to stimulating local demand for the feedstock. On the other hand, the case of ‘briefcase farmers’ was not straightforward. It was expected that these ‘briefcase farmers’ would be interested more in ventures which provide higher returns to investment which is not necessarily the case with *Jatropha* cultivation.

5.2.3.2 Welfare impacts of *Jatropha* cultivation using PSM

As a robustness check, selection bias was also modelled as a function of only observable covariates. The correlation coefficient (ρ) for the JCFs equation was not significant which satisfied the conditional independence assumptions, which entailed that PSM could generate unbiased and robust results.

The results of the PSM analysis presented in Table 22 showed large variations in the consumption expenditure per AEU between JCFs and NJFs. Depending on the type of algorithm used, the margin was significantly lower for JCFs by either 12,354 or 16,828.6 Kwachas for PSM and NN matching techniques, respectively. The PSM technique used 70 untreated observations, while the NN method selected 67 counterfactual households based on observable characteristics to match the treated units.

Table 22 Results of propensity score matching and nearest neighbour approaches in Malawi kwachas (Mwk)

Matching Algorithm	ATE (kwachas/AEU)	Standard errors	Test-statistic	Number of households	
				Treated	Untreated
Propensity Score					
Matching	-12,354	5,458.2	2.26*	96	70
Nearest Neighbour					
Neighbour	-16,828.6	8,301.8	2.03*	96	67

Notes: ATE refers to the average treatment effect on the treated, and * stands for significance at the 10% probability level. Test statistics are absolute values.

Source: Own survey, 2014.

The results from the PSM analysis do not support the notion that *Jatropha curcas* cultivation has significant welfare benefits for participating households. The PSM results returned statistically significant lower welfare outcomes for JCFs when compared to a statistically constructed counterfactual sample based on observable characteristics. These results differ from the ESR treatment effect on the treated estimates, which showed that the welfare benefits were at best zero. A possible explanation could be attributed to the fact that unobserved heterogeneity was not accounted for in the technique since PSM is based on pre-treatment observable characteristics only (Shiferaw *et al.*, 2014; Ahimbisibwe *et al.*, 2020). Nonetheless, PSM results from the two algorithms were consistent and robust.

5.5 Summary

This chapter used different methods to evaluate *Jatropha curcas*' welfare impacts measured as consumption expenditure per AEU for smallholders in southern Malawi. The analysis addressed the potential selection bias by employing the endogenous switching regression model and propensity score matching technique.

The descriptive analysis results indicated that the poverty headcount for *Jatropha curcas* cultivating farmers was higher than their counterfactuals. Other poverty indices such as the poverty gap and severity (depth of poverty) (P_2) were higher for *Jatropha curcas* cultivating

farmers than their counterfactuals. Overall, the endogenous switching regression results showed that welfare benefits for *Jatropha curcas* cultivation were at best zero. At the same time, NJFs expected consumption expenditure would decline substantially if they decided to cultivate *Jatropha curcas*. Furthermore, PSM results showed that after accounting for observable sources of selection bias, *Jatropha* farmers' welfare was significantly lower than that of their counterfactual (untreated group). Nonetheless, the analysis of conditional expectations for the five smallholder typologies suggests that for 'older uneducated smallholders' consumption expenditure would rise by 39.5%, followed by 'agricultural labourers' (35%) and 'briefcase farmers' (15%) if they decided to cultivate *Jatropha*.

Chapter 6 Conclusions, recommendations and proposed future research

6.1 Recapping the purpose of the study

The recent resurgence of biofuels at the global, regional, and national level is on account of the potential energy security, environmental concerns, and rural development objectives. The literature suggests that in the SSA region, the motivation is inclined more to the rural livelihoods development agenda than otherwise. Like other SSA countries, smallholders in Malawi face many shocks that threaten their food and nutrition security. Biofuel feedstock production has the potential to contribute to renewable energy as well as improving rural livelihoods. The literature on biofuels in Malawi is generally thin. The nexus of food security, livelihoods and biofuels feedstock production in Malawi has not been examined before - this study aimed at closing that knowledge gap.

Given the above, this study was conducted in the Mangochi District of southern Malawi, where BERL was receiving the bulk of *Jatropha curcas* seeds in 2014. The specific objectives of this thesis were to: (1) identify sources of smallholder heterogeneity and farmer typologies of *Jatropha curcas* producers to inform livelihood improvement interventions; (2) assess the effect of *Jatropha* cultivation on household resilience to food insecurity in Mangochi District, Malawi; and (3) evaluate the welfare impacts of *Jatropha curcas* cultivation on smallholders in southern Malawi.

Various techniques were used to study the objectives and increase the results' robustness; rigorous econometric methods were also applied. Multivariate analysis techniques were used in chapter 0 to analyse heterogeneity and determine typologies, opportunities, and constraints for livelihood improvement among energy crop producers. The assessment of determinants of resilience and the impact of *Jatropha curcas* cultivation employed the endogenous treatment model, which accounts for endogeneity and models the impact of participation (treatment). The Foster Greer Thorbecke (FGT) poverty indices were used in the descriptive analysis of the welfare of smallholders. The propensity score matching and endogenous switching regression methods were chosen to address potential selection bias from observable and unobservable sources, respectively.

The remaining part of this chapter presents the conclusions followed by recommendations in section 6.3. Possible areas for future research appear under section 6.4.

6.2 Conclusions

6.2.1 Smallholder typologies and implications on constraints and opportunities for improving livelihoods

The results in Section 3.3 demonstrated the need to consider heterogeneity in designing and implementing interventions and programmes for livelihood improvement. The empirical evidence indicated that smallholders are not resourced or constrained similarly because of their observed, salient, inherent, acquired, or social disposition. These factors highlight how heterogeneity complicates the formulation of appropriate interventions to achieve desired outcomes. Five different typologies were identified, which were generally distinguished by gender, asset holdings, labour endowments, level of agricultural input use, and output sales, i.e., land constrained, labour endowed, credit and extension constrained; resource-poor and female-headed; young agricultural entrepreneurs; and high resource endowed well-off smallholders.

The findings also demonstrated that based on the smallholders' unique characteristics, the *Jatropha curcas* cultivating farmers were not resourced and constrained in the same way as NJFs. Social indicators revealed that JCFs were poorly resourced, had less formal education, and had limited off-farm earning opportunities than NJFs. Generally, there was a higher proportion of JCFs in clusters described as low resourced with limited potentials/options for livelihood improvement than NJFs. These results showed that as compared to NJFs, JCFs were likely to be more vulnerable to food insecurity shocks. The analysis of variance results on selected characteristics revealed the distinguishing variables for the typologies, which can be used to refine the precision of targeted interventions for the typologies cluster. The features showed that different clusters demanded varying interventions based on variations in opportunities and their differences in constraints for livelihood improvements (see below).

Type I (agricultural labourers) farmers were more suited to labour-intensive strategies, including work for input programmes that can boost consumption and use of agricultural inputs

for food security. Type II (older-uneducated farmers) smallholders could benefit from tailor-made extension services, which can remedy the smallholders' limited education capacity. Type III (subsistence farmers) smallholders had a limited resource base for meaningful stand-alone interventions. As such, they were better candidates for free input support and safety net programmes. Type IV (briefcase farmers) smallholders were medium to high resourced smallholders who can be described as “stepping up” agricultural entrepreneurs that can be targeted for enterprise diversification in high-value market products. Type V (commercial farmers) smallholders were high resourced endowed smallholders who could be targeted for specialised interventions such as contract farming and seed multiplication. The results also showed that *Jatropha curcas* cultivation was unlikely to remain attractive for type IV and V smallholders who were inclined to invest in high input to output ventures. As such, *Jatropha curcas* cultivation could be best suited for typologies I, II and III smallholders who can be broadly categorised as a low to a medium resourced cluster.

6.2.3: The impact of *Jatropha curcas* cultivation on resilience to food insecurity.

The economic costs of shocks (stability) and the impact of weather variations (stocks variance) were important shocks that significantly lowered resilience to food insecurity. Strengthening capacity in weather forecasting through research in climate models, which generate accurate data, can accord smallholders a chance to take precautions. Existing dissemination channels (e.g., agriculture extension) could sensitize smallholders to invest in *ex-ante* strategies to reduce the impact of a weather shock. Strategies that transfer risks associated with weather variability remain important. Climate-smart agriculture offers viable options to mitigate the effects of weather variability while keeping a low carbon footprint.

The positive influence of access to basic services reaffirms the vital role public resources can play in increasing resilience to food insecurity. A well-educated and healthy labour force is indispensable for household income generation and increasing agricultural productivity, which is vital for increasing resilience to food insecurity. Increased access to basic services (such as better access to roads, schools, hospitals, etc.) reduces transaction costs and improves smallholders' labour productivity. The increased access to remote areas through all-weather roads can connect rural areas to markets, stimulating demand for products and services and increasing resilience to food insecurity. Better access to quality services like schools and

healthcare will improve labour productivity and contribute to creating a robust society that is resilient to food security shocks.

Access to agricultural extension services, and household education endowment's positive influence, demonstrated that factors related to human capital development need to be prioritised to increase resilience to food insecurity. Information and knowledge accessed through various formal (education, radio, extension services) and informal (farmer to farmer) sources play a central role in increasing the overall productivity of the household. The strengthening of existing extension communication channels and finding new effective strategies can potentially improve the delivery of extension messages. Moreover, increased access to education creates a learned workforce that can translate and assimilate agricultural innovations better and faster. The results showed that access to credit was also an important factor in increasing resilience to food insecurity. Affordable credit facilities to smallholders can support non-recipients of the AIP programme and increase input consumption (equipment, seeds, and fertiliser).

Education endowment was also a significant factor in increasing resilience against food insecurity. While the technology adoption literature suggests that the education of the household head is instrumental in the uptake of innovations, these results demonstrate the overall importance of education for all household members. Higher education endowments entail that members have access to more chances to access higher-paying off-farm jobs and secure future consumption (future incomes, remittances, etc.) in the longer term. The results suggest that the enhancement of quality education should be strengthened and prioritised.

The endogenous treatment effects results showed that *Jatropha curcas* cultivating farmers, particularly female-headed households, had significantly less resilience capacity to food insecurity compared to their counterparts. The conclusion is that the study did not find empirical evidence that *Jatropha curcas* cultivation increased resilience to food insecurity. The benefits from *Jatropha curcas* cultivation were intangible to make a substantial influence on household resilience.

6.2.2 Empirical evidence on the welfare impacts of *Jatropha* cultivation

The results in section 5.4 showed that after controlling selection bias from observed and unobserved covariate effects, welfare impacts of *Jatropha curcas* cultivation were non-existent compared to the untreated sample. Thus, there was no empirical evidence to support the perceived welfare impacts of *Jatropha curcas* cultivation at the current technology level (indigenous germplasm), know-how (commonly employed agronomic practices) and current business model in Malawi. In the absence of tangible empirical evidence on welfare benefits to feedstock producers, *Jatropha curcas* cultivation is unlikely to transform the lives of smallholders. It is also worth noting that biofuels are not a panacea that reduces rural poverty and improves the welfare of smallholders.

6.3 Policy recommendations

Various policy recommendations can be drawn from this study. The presence of heterogeneity among smallholders was demonstrated in the study findings. It is, therefore, recommended that development practitioners address heterogeneity in their programme interventions. Where capacity is available, tailor-made interventions for livelihood improvement such as income or crop diversification, public works for inputs, and safety nets need to target specific typologies based on smallholders' unique characteristics.

Gender imbalances revealed in the study findings also require special attention to increasing household resilience to food insecurity and promote welfare. Mainstreaming gender, as explained below, is another critical dimension that needs to be prioritised in all livelihood interventions. Development agencies need to circumvent a potential caveat of focusing on sectoral empowerment, which revolves around 'economic', 'political', or 'social' dimensions to a more holistic approach, alleviating the plight of female-headed households and transforming their lives. This can be achieved by targeting vulnerable female households with appropriate women empowerment programmes, which increase access to resources, develop their human capital, and strengthening their asset base (such as agricultural tools, equipment, and financial services).

To mitigate the effects of weather variability, there is a need to enhance preparedness and mitigation plans through increased smallholders' access to information on early warning

systems. There is a need to design new strategies and partnerships to disseminate early warning systems using ICTs like mobile phones. Another possible avenue worthy of exploring is creating synergies with other stakeholders like relevant government departments. The agricultural extension services can explore potential areas to build synergies with the Meteorological Department to improve the dissemination of information generated from the famine early warning systems. The agricultural extension service can be re-capacitated as an additional means of reaching out to farmers more effectively, leveraging on their existing mandate, which can improve smallholder mitigation plans.

To increase access to basic services, it is important for government efforts to increase accessibility to remote areas with all-weather access roads and quality essential services (such as education, healthcare).

Credit access is generally low in rural areas, with smallholders experiencing limited or non-existent financial services. The now-defunct Malawi Rural Finance Company (MRFC) previously provided agricultural credit and had a footprint in every EPA. The void left by MRFC has not been adequately filled. Given the result on the role of credit in increasing resilience to food insecurity, it is recommended that policy efforts that contribute to the development of rural financial services be promoted. These rural financial services need to design a portfolio of credit facilities tailored to address smallholders' agricultural credit needs. This can be achieved by integrating the rural financial markets into input and output markets. These credit facilities need to be linked to the mainstream financial markets in a way that does not unnecessarily burden them with heavy administrative overheads. The role of alternative rural banking solutions built on collective social capital, such as village savings and loans, can also be explored.

To increase the education endowment of households, this study recommends the promotion of several strategies. The older farmers can be targeted with adult literacy programmes to bring benefits associated with higher education, such as better understanding and higher chances to increased uptake of modern agricultural innovations. Older farmers can also be targeted with relevant extension methodologies (such as farmer field schools), which impart knowledge through creative demonstrations. On the other hand, the promotion of strategies that reduce dropout rates, especially for girls, will increase household education endowment. This can be

achieved by implementing programmes to improve the quality of infrastructure, discourage early marriages, empower youth with reproductive health services, quality teacher training, etc.

The results also showed a positive influence of assets on resilience to food insecurity and promoting welfare, which suggest that it is imperative to prioritise strategies that increase asset endowments. The significance of household asset holdings, including agricultural equipment, as an integral part of smallholder resilience to food insecurity has been presented in the empirical findings. Therefore, policy efforts should promote programmes that create assets for smallholders to build wealth, which serves a portfolio of functions. Notwithstanding the above, the strategies outlined might not be adequate to address the food insecurity problem without complementary economic opportunities.

The endogenous switching regression results showed that overall, there were no welfare benefits from *Jatropha curcas* cultivation. There is also a need for more empirical research on other potential biofuels to inform the Malawi biofuels policy in the future. Thus, future research must focus on developing and disseminating a portfolio of more profitable technology/practice packages of biofuels to contribute to rural household welfare. It is further recommended that out-grower schemes establish well-organised markets to facilitate the marketing of energy crops through well-coordinated information flows among stakeholders in the value chain. Based on discussions with farmers, smallholders suggested engaging in pre-season interphase negotiations with potential buyers to attain (i) improved farm gate prices for *Jatropha* in the following seasons, and (ii) improved commitment to strengthening marketing systems with more buyers.

Nevertheless, the analysis of conditional expectations also demonstrated that welfare impacts of *Jatropha* cultivation varied across smallholder typologies. Based on these findings, it is recommended that future efforts to promote *Jatropha curcas* cultivation should concentrate on three typologies of smallholders (‘agricultural labourers’, ‘older-uneducated’ and ‘briefcase farmers’) where participation was anticipated to bring some welfare benefits.

6.4 Study limitations and proposed future research

The study used a cross-sectional dataset which has limitations in the understanding of the temporal dynamics of resilience to food insecurity, the impact of *Jatropha curcas* cultivation on resilience capacity, and household welfare. Evidence-based policy processes can significantly benefit from analyses that have used panel data to study the dynamics of resilience to food insecurity and the welfare of smallholders. Where longitudinal data are available, analysts can extend the scope of the present study by investigating the temporal and spatial dimensions, which the current research could not address.

Resilience to food insecurity analysis is still evolving and how it is measured remains an integral part of scholarly and policy space. The multivariate techniques applied in this study relied on a specific set of variables that combined quantitative and subjective collates of food access, availability and perceptions on welfare. The variables used in this study were also not exhaustive, and a different context may demand a unique set of variables. Other household resilience index correlates also need to be tested in constructing the resilience index to assess their contribution to measuring the household resilience capacity. The addition of psychological capital can significantly enhance the analysis by explaining the role of other subjective components on resilience to food insecurity dimensions. Therefore, future research should also expand on the current study and incorporate the psychological capital dimensions (optimism, confidence, hope, etc.) in constructing the resilience index.

The global momentum in pursuit of environmentally friendly fuels to reduce the carbon footprint is likely to be sustained into the foreseeable future. The current study suggests that *Jatropha curcas* cultivation did not contribute significantly to rural household resilience capacity and household welfare. From now on, two choices need careful consideration: (i) abandon *Jatropha* entirely as a potential biofuel option for biodiesel production like other countries have done. Or (ii) focus future research on further development (agronomy, dominant trait selection/ breeding, business models, etc.) and disseminating a portfolio of scientifically proven profitable technology/practice packages. Notwithstanding the above, there is a need for more empirical research on other potential biofuels to inform the Malawi biofuels policy in the future.

The present study has shown that the welfare of biofuel feedstock producers was lower compared to their counterfactual. Future research can also consider understanding the behaviours of biofuel feedstock producers in agricultural markets to gain insights on how they can be engaged more profitably to improve their livelihoods. More precisely, what are the important drivers explaining market participation and the intensity of marketing their sales volumes in agricultural markets?

Lastly, due to other limitations, it was impractical to share these study findings with the communities where the data was collected for validation and further interpretations of results. In the spirit of responsible science, the study recommends that, where possible, future studies should plan, budget and conduct feedback sessions to validate and gain further interpretations of their findings.

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Appendix A. Tables

Appendix A.1 Frequency distribution of self-reported shocks in the previous 10 years

Description of shock	High (n)	Moderate (n)	Low (n)	Row Total (n)
Increase in input prices	113 (17)	15 (14)	2 (18)	130 (16)
Flooding	54 (8)	4 (4)	1 (9)	59 (7)
Death in the family	64 (9)	10 (9)	2 (18)	76 (10)
Outbreak livestock diseases	54 (8)	22 (20)	1 (9)	77 (10)
Decrease in output prices	22 (3)	9 (8)	0 (0)	31 (4)
Drought/Dryspells	23 (3)	12 (11)	0 (0)	35 (4)
Crop pests and diseases	27 (4)	23 (21)	0 (0)	50 (6)
Theft of livestock	1 (0)	8 (7)	0 (0)	9 (1)
Theft of stored crops	4 (1)	4 (4)	0 (0)	8 (1)
Theft of production assets	101 (15)	4 (4)	3 (27)	108 (14)
Physical disability	152 (22)	0 (0)	1 (9)	153 (19)
Loss of job by family member	62 (9)	0 (0)	1 (9)	63 (8)
Totals	677 (100)	111 (100)	11 (100)	799 (100)

Own Survey, 2014

Appendix A.2 Frequency distribution of self-reported shocks in the previous 12 months

Description of shock	High (n)	Moderate (n)	Low (n)	Row Total (n)
Flooding	36 (24)	4 (4)	22 (13)	62 (15)
Drought/Dryspells	10 (7)	12 (11)	9 (6)	31 (7)
Outbreak livestock diseases	17 (11)	22 (20)	31 (19)	70 (17)
Crop pests and diseases	9 (6)	23 (21)	27 (17)	59 (14)
Theft of production assets	8 (5)	4 (4)	3 (2)	15 (4)
Theft of stored crops	3 (2)	4 (4)	9 (6)	16 (4)
Theft of livestock	0 (0)	8 (7)	12 (7)	20 (5)
Loss of job by family member	1 (1)	0 (0)	0 (0)	1 (0)
Physical disability	2 (1)	0 (0)	0 (0)	2 (0)

Description of shock	High (n)	Moderate (n)	Low (n)	Row Total (n)
Death in the family	35 (23)	10 (9)	10 (6)	55 (13)
Increase in input prices	19 (13)	15 (14)	23 (14)	57 (13)
Decrease in output price	10 (7)	9 (8)	17 (10)	36 (8)
Totals	150(100)	111(100)	163(100)	424(100)

Own Survey, 2014.

Appendix A.3 Coping mechanisms used by households after shock encounters in the previous 12 months

Coping strategy	Total sample		JCFs		NJFs	
	Freq	%	Freq	%	Freq	%
Sold Assets	5	2	3	2	2	2
Sold livestock	8	3	6	5	2	2
Sold Crops;	13	6	4	3	9	8
Used savings	64	27	38	30	27	25
Borrowed money (informal)	57	24	33	26	24	22
Took a loan (formal lending)	2	1	2	2	0	0
Reduced consumption	2	1	1	1	1	1
Sought extension advice	58	25	30	24	30	27
Others	25	11	10	7	15	13
Totals	234	100	127	100	107	100

Own Survey, 2014.

Appendix A.4 OLS estimates of the effects of shocks on food consumption expenditure per AEU and RCI

Variable	Food security model	
		VIF
Resilience capacity index		
RCI	0.28*** (0.037)	1.63
HH control variables		
LandConstrnt	-0.296* (0.17)	1.18
Diversity index	0.11* (0.046)	1.38
Farmer Category	-0.005 (0.07)	1.21
Labour Availbty	0.058* (0.029)	1.17
copstrcount	0.001 (0.037)	1.13
Off-farm\$ access	-0.105 (0.065)	1.12
Aveduendwnt	-0.015 (0.02)	1.29
Acces2bsrvcs	0.033 (0.026)	1.05
ExtnFreq	-0.002 (0.012)	1.06
Credit Access	0.199* (0.082)	1.26
Shocks		
Stability	-0.065* (0.037)	1.07
StocksDiffrc	-1.26e-04* (5.4e-5)	1.38
Pc_Asset insecurity	-0.002 (0.023)	1.21
Pc_crop & livestock disease	0.021 (0.025)	1.12
Pc_Job loss and flooding	-0.012 (0.024)	1.06
Pc_High input prices	-0.015 (0.028)	1.07
Constant	9.661 (0.17)	
F-test	9.88***	-
R-squared/Adj R-squared	0.39	-
Mean VIF	-	1.2
N	286	

Own Survey, 2014.

Appendix A. 5 focus group discussions results on gender roles and livelihoods strategies

Livelihood Strategy	Gender involvement		Lingwena EPA (JCFs)		Maiwa EPA (NJFs)	
	Males	Females	Scores	Rank	Scores	Rank
	Farming (crops and livestock)	Yes	Yes	4	2	5
Fishing	Yes	No	5	1	1	4
Wetland cultivation (Dambo cropping)	Yes	Yes	3	3	4	2
Forest based economy						
- Fetching and selling wood & bamboo	Yes	Yes	n.a	n.a	1	4
- Charcoal burning	Yes	No	n.a	n.a	1	4
Small enterprises						
- Petty trading: fish & Others	Yes	Yes	1	4	4	2
- Milling and selling rice	No	Yes	1	4	n.a	n.a
- Making doughnuts.	No	Yes	1	4	1	4
- Beer brewing	No	Yes	1	4	1	4
Skilled labour						
- weaving	Yes	Yes	1	4	1	4
- making ropes (pulling fishing nets)	Yes	No	1	4	2	3
- tailoring	Yes	No	1	4	1	4
- bricklaying	Yes	No	1	4	1	4
Casual labour	Yes	Yes	3	3	2	3
Remittances (from South Africa)	Yes	No	1	4	2	3
Total scores			24		27	

Own Survey, 2014.

Appendix A. 6 Cross-tabulation results of input use, outcomes by gender and soil fertility

Variable\ Category	JCFs (n=95)			NJFs (n=203)		
	Male- headed	Female- headed	T-test /Chi ²	Male- headed	Female- headed	T-test /Chi ²
Land holdings (ha)	1.38 (1.2)	0.99 (0.8)	1.56	1.48 (1.19)	1.1 (0.78)	2.42*
Agric.Equip index	-0.1 (1.43)	-1.11 (0.91)	3.35**	0.35 (1.37)	-0.27 (1.23)	2.95**
Fertiliser use (kgs/ha)	78.86 (110.9)	50.9 (54.6)	1.23	119.25 (120.5)	70.98 (63.5)	2.87**
Agricultural income (Mkw)	44,206 (105,807)	7,270 (19,036)	1.76*	47,929 (75,674)	53,861 (124,464)	0.41
Foodprodn level (1= adequate)	0.13 (0.34)	0.04 (0.20)	1.70	0.14 (0.029)	0.23 (0.056)	2.09
Off-farm income (Mkw)	86,238 (161,073)	29,050 (53,046)	1.77*	108,771 (180,337)	68,067 (134,418)	1.75*
	Fertile	Not Fertile		Fertile	Not Fertile	
Land holdings (ha)	1.46 (1.38)	1.2 (0.97)	1.02	1.49 (1.51)	1.33 (0.92)	0.86
Fertiliser use (kgs)	60.70 (65.79)	90.54 (122.98)	1.17	91.60 (126.2)	99.64 (100.55)	0.47
Foodprodn level (1= adequate)	0.19 (0.40)	0.073 (0.26)	2.88*	0.17 (0.37)	0.17 (0.38)	0.0004
Agricultural income (Mkw)	67,663 (158,464)	21,450 (43,384)	2.23*	38,780 (56,666)	53,514 (101,359)	1.01

Notes: JCFs= Jatropha cultivating farmers, NJFs=Non-Jatropha farmers. The significance levels: * ($p < 0.1$). Standard deviations in the parentheses

Source: Own Survey, 2014.

Appendix B: Household questionnaire _ Malawi biofuels study

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- C. SICKNESSES AND INJURIES (Ask for period between January to June 2014)
- D. LOSS/DEATH OF FAMILY MEMBER INFORMATION (Ask for period 2010 to 2014).
- E. LIVESTOCK REARING AND MARKETING INFORMATION
- F. HOUSEHOLD OFF-FARM INCOME
- G. LAND AND CROPPING PATTERNS
- H. ACCESS TO NATURAL RESOURCES
- I. ACCESS TO PUBLIC AMENITIES AND SERVICE
- J. HOUSEHOLD FOOD ECONOMY

Introduction and declaration :(*Spoken by the enumerator*)

My name is _____. I am facilitating data collection for a research project by a University of KwaZulu Natal postgraduate student, who is also our team leader. The research is looking at growing energy crops and other livelihood activities affecting people living in your area to see how it can be improved. Some households have been selected in a survey regardless of whether they grow energy crops to participate in the survey, and your household happens to be one of them. Please note that there are no wrong or right answers in this survey but we kindly ask you to answer honestly. There are no rewards/offers in return for participating in the interview but we value your answers and opinions shared during the interview. I promise you that there will be total confidentiality of the responses from this interview. You are also free to discontinue with the interview when you feel so and there will not be any consequences to that choice.

Are you willing to participate in the survey? _____ Codes: 1=Yes, 2= No. If yes proceed with interview Signature of participant:

IDENTIFICATION

Personal Data	Location & Period Data
Enumerator:	Date of interview:
Supervisor:	ADD: RDP:
Date Reviewed:	EPA:

Agriculture development division (ADD) :

Rural development programme (RDP):

Extension planning area (EPA):

A.- HOUSEHOLD DEMOGRAPHICS AND SOCIO-ECONOMIC INFORMATION

Q1.	Name of Respondent	Q2.	Gender	Q3.	Age	Q4.	Marital Status
Ans.		Ans.		Ans.		Ans.	

Codes: Sex: 1=male, 2= female; Marital Status: 1= Single 2= married 3=Separated/divorced 4=Widowed

Q5. Household membership –List of all members

Member's name	Sex: (1= M 2=F).	Relationship ² HH (see codes below)	Age (yrs.)		Educ. level attained (highest class reached)	Working status on the farm. (See codes below)	Primary Occupation <i>Codes: 1. Agriculture (years farming); 2. Petty trading/Vendor; 3. Brickmaking 4. Brewing alcohol. 5. Baking. 6. Student. 7.Others (specify)</i>	Secondary Occupation <i>Codes: 1. Agriculture; 2. Petty trading; Vendor; 3. Brickmaking 4. Brewing alcohol. 5. Baking. Others (specify)</i>
			>5 yrs.	<5 yrs: months				
1								
2								
3								

4								
5								
6								
7								
8								

Codes: R2HH (1=Self; 2= Spouse; 3=Son/Daughter; 4= Parent; 5= Grandson/daughter; 6= Others Specify). Working Status: (1= full time, 2= part time, 3= N/A)

Social Status & Standing in Society

Q6. Do you hold any leadership/committee position in the village? _____ Code: 1= Yes, 2= No. If Yes go to Q 7.

Q7. What position do you hold in the village? _____

Code: 1= village headman, 2=club chairman, 3= club member (Specify), 4= party member (specify), 5= member of religious institution, 6= minister to village headman, 7= others, specify.

Household Assets

Q8. Indicate in the table below if the household has any of the following assets.

Household Asset Owned?	Tick (√) against item owned	What is the number of units of the asset owned?	What is the current estimated value of the asset owned? (Mwk)	Household Asset Owned?	Tick (√) against item owned	What is the number of units of the asset owned?	What is the estimated value of the asset owned? (kwachas)
Radio				Plough/ Ridger			
Bicycle				Sprayer			
Mattresses/mats				Car/Pick-up truck/Tractor			

Blankets				Irrigation cans			
Beds				Granaries (<i>nkhokwe</i>) with food			
Television				Treadle pump			
Tables				Ox-Cart			
Chairs				Cell phones			
Sofa set				Pangas			

B.- RISKS AND SHOCKS (Ask for the last 10 years).

	1. Was the family affected by any of the following events from 2004 to this date?(Last 10 years) <i>Code: 1-- Yes 2--- No > proceed to next section C.!</i>	2. Rank 3 most significant shocks; <i>Code: 1. Most severe 2. Second most severe 3. Third most severe.</i>	The following questions to the right should focus on the three most severe shock only	3. When did this event occur? <i>(Provide the year and if it was recurrent provide the sequence)</i>	4. How big was the impact of this event? <i>Code: 1. High 2. Moderate 3. Low. 4. No impact</i>	5. What would be the value of the loss due to this event? <i>(kwachas)</i>	6. What mechanisms did the HH use to cope with this stress? <i>(List as many as possible) (See codes below)</i>	7. How long did it take for the family to survive /overcome this shock? <i>(Indicate period in months or years where necessary)</i>	8. What measures, if any, did the family put in place in case this event reoccurs? <i>(List as many strategies as possible?) (specify- Use Notes line below if necessary).</i>
1	Flooding								
2	Drought/Dry Spells								
3	Outbreak of livestock diseases								

4	Pest and disease affecting crops								
5	Theft of production assets								
6	Theft of stored crops								
7	Theft of livestock								
8	Loss of job by family member								
9	Physical disability of family member								
10	Death of family member								
11	Increase in input prices								
12	Decrease in output prices								

Codes: 1. Sold Assets; 2. Sold livestock; 3. Sold Crops; 4.Used savings; 5. Borrowed money; 6.Took a loan; 7. Reduced consumption; 8. Sold land. 9. Sought extension advice. 10. Others (specify- Use Notes line below if necessary)

Notes:

C.- SICKNESSES AND INJURIES (Ask for period between January to June 2014)

I will now ask about sicknesses and injuries suffered by household members from January 2014

	1. Did this member of the family suffer from any illness or injury? <i>Code</i> <i>1-- Yes</i> <i>2--- No > proceed to next!</i>	2. Provide more information on the illness or injury. (list three important ones only) <i>See codes below the table:</i>			3. Explain how the problem/illness was managed? <i>See codes below the table:</i>			5. How much money or resources were spent on this individual in mgt of this illness? <i>(kwachas)</i>	6. Did the illness/problem stop the member from discharging their daily chores? <i>Codes: 1.Yes</i> <i>2. No --> Skip Q7 &8.</i>	7. How many days did the member refrain their normal activities? <i>(Indicate period in days/months or years where necessary)</i>	8. What measures, if any, did the family take as precaution if an event reoccurs? (List as many strategies as possible?) <i>Provide for most important illness (specify- Use Notes line below if necessary).</i>
		#1	#2	#3	Illness #1	Illness #2	Illness #3				
1											
2											
3											
4											
5											
6											
7											
8											

Illness codes: 1. Malaria, fever; 2. Diarrhoea; 3. Respiratory problems; 4. TB; 5. Asthma; 6. Maternity problems; 7. Dental Problems; 8. Eye /ear problems; 9. Mental problems; 10 Others(specify)_____

Illness Mgt: 1. Took drugs kept in the house; 2. Sought care at govt hospital; 3. Sought care at private hospital; 4. Took traditional medicine; 5. Bought pain relief tables from local vendor; 5. Did nothing; 6. Sought care from traditional healer; 7. Others
:(Specify)_____.

D.- LOSS/DEATH OF FAMILY MEMBER INFORMATION (Ask for period 2010 to 2014).

I will now ask you about bereavement in the family in the last 5 years (from 2010).

1. Has the family experienced death of one of the members closely associated with this family in the last 5 years (since 2008)? (If yes, list the names of the deceased below)	2. What was the Relationship to the head of the household? <i>(1.Head; 2. Spouse; 3=Son/Daughter; 4= Parent; 5= Grandson/daughter; 6= Others Specify).</i>	3. When did the family member died? (indicate the year here)	4. State the age of the deceased at the time of death?		5. State the cause of death for the family member. <i>(1. Accidental death; 2.Long term sickness; 3=Sudden death; 4= Common known diseases (malaria, etc.); 5=Suspected witchcraft; 6=Maternity complications; 7. Others (Specify).</i>
			Years	months	

E.- LIVESTOCK REARING AND MARKETING INFORMATION

I will now ask you about livestock and livestock sales in 2012/13 season (Complete the table below).

Q1. Do you own/rear livestock? _____ Codes: 1. Yes; 2.No. If Yes, please complete the table below

Q2. Type of livestock	Q3. How many of this type of livestock do you currently have?	Q4. Have you sold any in the last year? <i>Codes: 1 Yes; 2. No</i> <i>If Yes -- >Next Q5. If yes proceed to Q6.</i>	Ask the following Questions only for households keeping livestock	Q5. How many units have you sold in the last year?	Q6. What is the current market price for one unit of this type?	Q7. What is the total amount of money raised from sales of this type of livestock in the 2013/14 season (Kwachas)	Q8. What are the estimated production costs for this livestock type (feeds, labour, medicines, etc.)	Q9. What is the total value of the livestock owned; assume all was sold for cash? (Kwachas)	Q10. How much income was raised if you sold any products (milk, hides or eggs) in 2012/13 season? (kwachas)	
Beef Cattle										
Sheep (<i>ngondolo</i>)										
Goats										
Chickens										
Guinea Fowl										
Pigeons										
Pigs										
Ducks										

Rabbits									
Turkeys									
Dairy Cattle									
Donkey									

F.- HOUSEHOLD OFF-FARM INCOME

Q1. What other sources of income do you have in the household? Provide data on income for the 2013/14 season?

2. Income Source		3. What is the monthly income/or how much is earned and how often in a year? (provide indication of frequency that average income is earned here)	4. What is the estimated annual income earned from this activity for the 2013/14 season?	5. Where is this livelihood option conducted? Codes: 1. Homestead; 2. Along the road, 3. Local market; Nearby town; 4. Local Market; 5. Near urban area; 6. Roving markets; 7. Others; Specify(_____)
1	Formal Employment			
2	On-farm Seasonal employment (<i>ganyu</i>)			
3	Off-farm seasonal			
4	Commercial Enterprise (non-agricultural, e.g., Shop)			
5	Skilled work (brick layer, carpenter, etc.)			

6	Petty Trading (e.g., Vending)			
7	Agro-processing (e.g., Beer brewing, baking, selling cooked green maize)			
8	Remittances			
9	Others			

G.- LAND AND CROPPING PATTERNS

Q1. How many plots does the household have at present? _____ Please complete the table below for specific plot information. Suppose there is somebody more conversant with this information, please let them participate in answering.

Plot #	2. What is the size of this plot?		3. How far is this plot from the homestead. <i>Code:</i> 1. Around homestead; 2. Away from homestead	4. What is the primary target crop for this land? <i>Codes;</i> 1. Maize; 2. Beans; 3. Cassava; 4. Soybeans; 5. G/nut; 6. Pigeon peas;	5. What type of cropping pattern is practiced on this piece of land? <i>Codes: 1. Pure stand; 2. Intercrop/ Mixed cropping; 3.</i>	6. Who is responsible for management of the plot? <i>Codes: 1. Husband; 2. Wife; 3. Both; 4. Hired labour; 5.</i>	7. How was this plot acquired? <i>(see tenure codes below)</i> <i>(if rented → next, otherwise</i>	8. What is the cost for renting the piece of land? <i>(kwachas)</i>	9. What is the fertility status of this plot? <i>(see codes below)</i>	10. How much inputs were used on this plot this season?
	ha	Acres								

					1 st Crop	2 nd Crop	Fallow; 4. Rotation	A combinati on	skip to Q13).			Seeds		Fertilizer		Hired Labou r (Mwk)	Irrigati on (Mwk)	
												Q	unit	Q	Un it			
1																		
2																		
3																		
4																		
5																		
6																		
Total Area																		

Soil Fertility Codes: 1. Fertile doesn't require added inputs; 2. Average requires moderate input; 3. Not fertile can't produce without added inputs; 4. Marginal land

Tenure status? Code: 1. Inherited from paternal side; 2. Inherited from maternal side; 3. Given from the chief; 4. Bought from another person 5. Free borrowing; 6. Rented @ a cost

Q11. Do you have access to wetland (*Dimba*)? _____ Codes; 1. Yes and 2. No . If No proceed to Section H.

Q12. If yes, What is the tenure status of this wetland? _____ Codes; . 1. Inherited from paternal side; 2. Inherited from maternal side; 3. Given from the chief; 4. Bought from another person 5. Free borrowing; 6. Rented @ a cost

Q13. Type of <i>Dimba</i> crop cultivated	Q14. Estimate how much was harvested 2013/2014 season?	Q15. How much was sold in 2012/2013 season?	Q16. What was the average price per unit?	Q17. How much was raised from sales of this crop?
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	Quantity	Unit	Quantity	Unit	2013/14	2012/13	(kwachas)
Green maize							
Tomatoes							
Onions							
Leafy Vegetables							
Other (specify)							
Other (specify)							

H.- ACCESS TO NATURAL RESOURCES

Q1. Do you have access to any of the resources mentioned below? _____ Codes: 1.Yes; 2. No. If Yes, proceed to completing the table below.

2. Type of natural resource	3. How far is this resource from your home?		4. What is the accessibility of this resource to people from the village? <i>Codes: 1.Open access; 2. Restricted access; 3. Permit holders; 4. Others (specify)_____</i>	5. Over the last decade, what changes have you noticed on the resource? <i>Codes:1. Increasing; 2. Constant; 3. Decreasing;</i>	6. What regulations exist, if any, governing access to this resource?	7. How has the quality of the resource changed over the last decade? <i>Codes; 1. Improved/increased; 2. Constant; 3. Diminished/Declined;</i>	8. What has been done to reverse/ arrest/improve the condition mentioned in the previous question? <i>Codes: 1. Nothing; 2. Set rules on accessibility; 3.Controlled access (permits etc.); 4. Restoration activities (reforestation etc.); 5.Others (specify_____)</i>
	Distance (km)	Walking time (hrs)					
Water resources for irrigation							

Fish from a river							
Wetlands (<i>Dambo</i>)							
Forest Resources (timber & non-timber products)							
Grazing land							
Others (Specify:___)							

J.- ACCESS TO PUBLIC AMENITIES AND SERVICE

Q1. Describe your access to the following amenities:

Q2. Name of infrastructure	Q3. What means do you regularly use to access the following? <i>Code:1. Walk, 2. Bicycle; 3. Public transport; 4.Others (_____).</i>	Q4. How long does it take you to get to the service point in question? <i>(Hours)</i>	Q5. Are services at this access point free of charge? <i>Codes: 1. Yes, 2 No</i> <i>If Yes → Answer the next question that follows</i>	Q6. Describe what kind of regulations govern access to the service facilities in question
Public Hospital				

Public Clinic				
Primary School				
Public Secondary School				
Local Market				
Water point (e.g., bore-holes)				
Public telephone/call box				

Access to Extension Services:

Q7. Do you have access to agricultural extension services of any type in your area? _____ Code: 1= Yes, 2= No If No skip to Q13

Q8. What kind of services do you access from the agricultural extension officer in your area? _____ Codes: 1. Crops production; 2. Animal husbandry; 3. Forestry extensions; 4. Energy crop management; 5. Others (Specify_____)

Q9. How often do you meet the extension staff? _____ Code: 1= Once / wk., 2=twice/wk., 3= once/ fortnight, 4= once / three wks., 5=Once / month, 6= Once/ two months, 7= Only on field days, 8= None.

Q10. Have you previously received any extension services regarding management and handling of energy crops? _____ Code: 1= No, 2= Yes ; if Yes → Answer next Question.

Q11. What have you learnt on energy crop management and handling from the extension workers? _____ Code: 1= Crop production agronomy , 2= Pest and disease control, 3= Harvesting and processing, 4= Product preparation for sale, 5= None; 5=Others (Specify_____).

Farmer Access to Credit

Q12. Did you receive any other credit in the last season? _____
Code: 1=Yes, 2= No. If yes, answer the next Q. if No go to Sect: K

Q13. What kind of loan was it? _____ Code: 1= Non-Agricultural loan, 2= Agricultural Loan

Q14. How did you receive it? _____ Code: 1= As a group, 2= As an individual.

Q15. Where did you get credit from? _____ Code: 1.=MRFC, 2.= FINCA; 3. NGO; 4= MALDEF, 5= Village bank; 6= Neighbours; 7. Relatives; 8.Loan Shanks. Others,(specify) _____).

Q16. What were the terms on this loan accessed above? ____ Codes: 1. Principal and interest; 2. *Katapila*; 3. Payment in kind (produce); 4. Interest free loan (principal only). 5. Others (specify; _____)

Q3. What is your general level of food production? _____; Code: 1= Surplus, 2= generally enough, 3= generally not enough.

Q4. When did you first start using produce from last harvest _____ (month)?

Q5. When the food/harvest is finished, what measures do you take to cope with the situation, if it does not last till the next harvest? _____ Codes: 1. Purchases; 2. Reduce meal frequency; 3. Eat less food; 4. Work for food; 5. Work for cash; 6. Gift from friends and relatives; 7. Rely on food aid programs (NGOs); 8. Social cash transfers; 9.Others (Specify _____)

Q6. Who would you say are the most important persons who bring income and food to this family _____ (Refer to the list of household members and write only the code in the space above).

Q17. Which activities were supported/financed from this loan? _____ Code: 1= helped to buy fertilizers, 2= helped to buy seeds for food crops; 3. Helped to buy seeds for energy crops; 4= finances a non-agricultural commercial enterprise; 5. None, 6= Others, specify: _____.

Q9. Are you willing/ planning to grow energy crops this coming season? _____ Code: 1= Yes, 2= No. If Yes, replacement or addition? _____

If Yes, why? _____

HOUSEHOLD FOOD ECONOMY

Q1. Apart from maize, what are the other major sources of food consumed by the family? _____ Codes: 1. Sweet potatoes; 2. Sorghum; 3. Cassava; 4. Pumpkins; 5. Rice; 6. Millet; 7. Others

Q2. What are the main sources of your food consumed in the family? _____ Codes: 1. Own production; 2. market purchases; 3. Food for work; 4. Cash for work (*ganyu*); 5. Social cash transfers; 6. Gifts from family & friends; 7. Others

Q7. Catalogue of food expenses

Did the household spend any money on the following items between July 2013 and June 2014?		How often? (freq.)	Quantities purchased per period?	What was value of each purchase?
Cod e	Food Items			
1	Maize, maize flour			
2	Rice			
3	Millet			

4	Sorghum			
5	Cassava, Sweet potatoes			
6	Wheat, wheat flour			
7	Sugar, tea, coffee, Milk			
8	Salt			
9	Cooking oil, Margarine			
10	Meat,			
11	Fish (<i>bonya</i>)			
12	Beans, peas, Cowpeas			
13	Fruits (<i>zipatso</i>)			
14	Others (please specify) :xxx			

Codes: 1-Daily; 2. Weekly; 3. Bi-weekly; 4. Monthly; 5. Quarterly; 6. Bi-annually; 7. Annually

Q8. Provide information on the non-food purchases made over the last 12 months? (June 2013 to July 2014).

Did the household spend any money on the following items between January and June 2014?	How often?	# of purchases per period?	What was value of each purchase?
1	Electricity		

2	Paraffin			
3	Candles			
4	Batteries			
5	Charcoal			
6	Firewood			
7	Telecom (charge, airtime, repairs, etc.)			
8	Toiletries (soap, lotion,)			
9	Saloon costs(hair dressing)			
10	Barbershop costs			
11	Gasoline/diesel			
12	Transport costs			
13	School fees			
14	School uniform			
15	Pocket money			
16	Stationery			
17	Kitchen Items (pots, plates)			
18	Clothes for kids			
19	Clothes for father			

20	Clothes for mother			
21	Entertainment (drinks etc.)			
22	Funeral expenses			
23	Loan repayments			
24	Remittances			

Codes: 1-Daily; 2. Weekly; 3. Bi-weekly; 4. Monthly; 5. Quarterly; 6.Bi-annually; 7.Annually.

Is there any question you would like to ask me at this point?

Please indicate response made by the interviewer here for future references

Question 9 (Optional)

Is there any issue or any agriculture-related point that you would like to inform us about?

This marks the end of the interview with you. I would be grateful if you will allow me to interview you again next time if necessary. I thank you for your time and patience in answering all these questions.



Appendix C: Checklist for Focus Group Discussions_
Malawi biofuels study

The nexus of food security, livelihoods, and biofuels production: the case of *Jatropha curcas* feedstock production in Malawi

Objective: The objective of this FGD is to capture information on farmer’s practices, knowledge in management of energy crops, perceptions on benefit, constraints and other livelihood implications on growing energy crops.

Note to the Facilitator

This is only meant to provide guidance and scope to the discussions. As such it is not necessarily important to ask every question / issue in the order in which they appear nor is it supposed to be an exhaustive list because some issues requiring further probing may arise in the course of the discussion. As a Facilitator, just introduce the main issues to be discussed, and avoid guiding the discussions. Ensure that there is adequate participation from all the group members. Keep your mind open and proceed with the flow of the discussions. While side-tracking should not be completely discouraged, please ensure that most of the discussion revolves around the main issue.

ISSUES	METHOD	INTERVIEW GROUP
<p>1. FARMING SYSTEMS</p> <p>a) existing cropping patterns</p> <p>i. What is the average acreage per household in the village?</p> <p>ii. What are the major crops which you cultivate?</p> <p>iii. How do you plant the crops in the main field? (Pure stand, intercroops, relay crop etc.)</p> <p>iv. What cropping pattern is used for growing energy crops?</p> <p>v. Discuss the reasons for choosing the above options.</p> <p>vi. How is livestock rearing practices in the areas? (Open grazing, stall feeding, etc.)</p> <p>b) Land, Access, ownership</p> <p>i. How is land acquired in the village?</p> <p>ii. Who owns the land in the family and how is the right to ownership “on-passed” when a person dies?</p>	SSI	Smallholder farmers

<p>iii. What rules govern the use of designated/protected/fragile environment or ecosystems in the village v. How are these rules made? Do ordinary people have a say in making of these rules?</p> <p>c) Other livelihood strategies - Other than farming, describe other activities people in the areas do to make a living (Collecting /gathering firewood, brick making, weaving & thatching etc.)</p>		
<p>2. ENERGY CROP MANAGEMENT &MARKETING a) Origins, common practices & trends. i. How were you introduced to growing energy crops? ii. What kind of extension support did you receive on the agronomy on growing energy crops? iii. What is the main source of seed for energy crop? iv. What were the terms at first access? v. Have you harvested any crop yet? If Yes, from your experience, what are the yields recorded for the past three years? vi. Which tasks are more labour demanding and when usually does this activity take place? vii. How do you balance peak labour demands with operations on tradition crops (food &cash crops) viii. Who buys the energy crops in the areas? ix. What prices is offered for a defined unit (e.g., Kilogram)? x. What yield variations have you seen from the time you started getting the yields? xi. How has this price changed over the last three years? xii. How is this prices arrived at? Do you have a change to negotiate a price when registering or at the sales point? xiii. Are you generally happy with the prices offered for your crop at the sales point?</p>	<p>SSI Scoring and Ranking for i, iii, & xiii.</p>	<p>Smallholder farmers & extension workers.</p>
<p>2. ACCRUED BENEFITS FROM ENERGY CROPS a) Motivation, accrued benefits & constraints to profitability. i. What benefits have you so far noticed from growing energy crops? ii. What would you say was your major motivation to start going energy crops? iii. What are some of the constraints faced in. - Growing energy crops? - Marketing of the energy crops? iv. What kind of support do you think is required to improve profitability of growing energy crops? v. What kind of business arrangements exists between the smallholder farmers (feedstock producers) and buyers? (Do you have formals contracts with agreed prices and what other terms exist in this arrangement?) vi. What would you like to see changed from the current way you relate with the buyers of energy crops?</p>	<p>SSI Ranking for i, iii, iv, & vi.</p>	<p>Smallholder farmers & extension workers.</p>
<p>3. FARMER PERCEPTIONS a) farmers subjective perceptions. i. Do you think growing of energy crops is beneficial to smallholder farmers? If yes,</p>	<p>SSI</p>	<p>Smallholder farmers & extension workers</p>

<p>ii. Discuss the reason why they think so?</p> <p>iii. In your perceptions, what are the constraints of growing energy crops as a livelihood strategy?</p> <p>iv. How can the current constraints be address from your perspective?</p> <p>v. why are a lot of people not growing the energy crops?</p> <p>vii. How can more people be encouraged to grow energy crops?</p> <p>v. In your opinion, do you think energy crops pose a food security threat?</p> <p>vi. Discuss the issues reasons for the response provided above</p> <p>Vii. What are you opinions on the fertilizer subsidy programme? (targeting, implementation, and outputs)</p>	<p>Scoring and Ranking for ii, iii, v & vii.</p>	
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ⁱ The biofuel from jatropha seeds is produced for domestic blending with diesel up to 8% and in paraffin used for lightening (Government of Malawi, 2013).