Dissertation

Evaluation of Jatropha Biofuels Value Chain for Sustainability and Food Security:

A Conceptual Framework Approach

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Abstract

When the biofuels agenda gained momentum globally, many SADC member states considered to implement biofuels (take note: not bioenergy) programmes as they looked at the potential to diversify the agriculture sector and foster rural development in the region. Several projects, driven mainly by foreign investors, were introduced and implemented in the region but (most if not all) failed to deliver on the promises and left many people desperate. This eroded the trust that governments had in biofuels significantly. As a result, many SADC countries condemned Jatropha-based biofuels and even pronounced measures to discourage the introduction of biofuels as they feared that it would impact negatively on food production, the environment, economy and the people.

Most of the SADC member states' biophysical conditions are potentially suitable to grow most of the suggested feedstock crops as there seem to be a comparable abundant suitable land to grow both energy and food crops. This is true especially for Angola, DRC, Mozambique, Tanzania and Zambia. Even though the SADC region has agricultural ecological conditions and adequate policy framework that can support most biofuels feedstock production, there is very little evidence to show on the ground in terms of biofuels projects except for the ethanol generation capacities and programme in Malawi, Mozambique, South Africa, and Zimbabwe.

This study contributed to finding possible solutions to a very complex problem of biofuels value chain development, food security and sustainability by evaluating the potentials, conditions and challenges of agro-based feedstock production systems in the SADC region. A conceptual Diversion-Based Evaluation Framework (DBEF) that integrates other assessment tools was developed and applied to evaluate potential diversions and their impacts at project, national and/or even sub continental-region levels. A mixed methods research design approach to inquiry that combines both qualitative and quantitative empirical methods was therefore adopted to conduct this research. It involved conducting experiments to assess the potential of Jatropha and other energy crops in relation to biophysical conditions, CO_2 sequestration and climate change mitigation, development of a diversion-based evaluation framework (DBEF), conducting questionnaire driven surveys, interest and expert groups interviews, performing target beneficiary assessment and meta evaluations of implemented projects for sustainability and food security using the framework.

Several projects implemented using different feedstock production models in four SADC countries were used to evaluate biofuels value chain development risks against sustainability and potential to harm food production and food security. Diversion of land was found to be of considerable high risk for investor and PPP driven models even in countries with abundant arable land and water (due to potential displacements) while farm input diversions (e.g. labour, finances, extension services) were identified to pose potential high risk for out-grower production models.

This study concluded that a hybrid integrated approach to designing policies and programmes for biofuel value chains that puts local needs and context, triangulated with national or Africa sub-continental macro-economic needs aspects, is critical for sustainability than a neo-liberal top-down approach. The later tend to create dependencies that can cause disruption of food production systems, markets and possible irreparable damage to people's livelihoods and the environment in medium to long terms.

Table of Contents

List of Figures

List of Tables

1 Introduction

This introductory chapter presents an overview of the entire work from background, problem statement and methods to sketching how the thesis is structured as an interrogative piece of work. The chapter builds the case slowly from global pronouncements and drivers of biofuels and gives a motivation to why this study was necessary. It further introduces the main reasons for selecting three SADC countries as a case study area. It highlights key critical results and main recommendation for further work.

1.1 Quest for biofuels development

The quest to sustain the existence and lifestyle of humanity is increasingly becoming a major challenge. A significant progress in the global north has been achieved to remove main socio-economic development hurdles and inequalities, although the latest Inclusive Development Index (IDI)[1] Report of the World Economic Forum indicates a widening political polarity and erosion of social cohesion in these advanced and emerging economies. At the same time, countries in the global south, especially Sub-Saharan African countries, continue to face many challenges to achieve acceptable food, shelter, water and energy securities with over 413 million of its population living on less than USD 1.90 a day in 2015 (WORLD BANK GROUP 2018).

Global warming and its associated impacts on ecosystems' ability to provide various services to all kinds of life and its forms, is constantly under threat. The past 100 years are a key period for understanding climate variability and climate change as it marks a transition period from climate system, dominated by natural influences, to that which is significantly dominated by anthropogenic activities (BRÖNNIMANN 2008). With various direct and indirect anthropogenic climate change impacts, modern civilisation is under significant pressure to achieve sustainable socio-economic development. 2^{o}C threshold in temperature increase is a tipping point with the world predicted to experience major climatic change induced impacts.

[1] Inclusive Development Index, designed by the World Economic Forum, is an alternative measure of performance of economies that reflects more closely the criteria by which people evaluate their countries' economic progress

Africa is warming faster than the global average with projections of rise of 1.5^{o}C - 3^{o}C this century, making climate change a considerable health and economic challenge for the continent (UNEP 2016). Northern and Southern Africa will become much hotter (4 ^{o}C or more) and drier (precipitation falling by at least 10-20 %). The drought risks in southern Africa are related to the occurrence of the El Niño phenomenon in the Pacific and there has been a tendency for these to become more prolonged and frequent (COLLIER 2008).

All these are negative impacts of climate change have necessitated the UNFCCC to develop *adaptation* and *mitigation* strategies that have been translated into global, national and regional policies. With a population of over 7.3 billion people roaming on our planet today, the urgency to find solutions to reverse or at least reduce these impacts is now as desperate as it can be. Paris Agreement (adopted in 2015) set the specific goal of holding global warming to a well below 2^{o}C threshold compared to pre-industrial era levels and pursuing efforts to limit warming to 1.5^{o}C by 2050.

Many policy measures and strategies have been designed and implemented to reduce the anthropogenic GHG[2] emissions into the atmosphere from fossil-fuel used in electricity generation, combustion engines and land use change**.** CO_2 has been recognised to be the main culprit responsible for global warming and climate change**.** It is projected that demand for fossil fuel will continue to escalate as incomes rise especially in both industrialised and industrialising global south due to increase in disposable income, according to the World Energy Outlook 2012. While efforts are being made to increase efficiency levels in automobiles to reduce the amount of fuel needed per km, the increase per year in motor vehicles numbers erodes these efforts very quickly.

Finding alternative solutions to fuel our mobility to maintain our current lifestyles requires resolute decision to reduce GHG globally. Biofuels have been considered as one of the options to transition from a fossil-fuel-depended transport sector to a much cleaner source as they are seen to have a positive net energy balance (NEB[3]). It is this

[2] Green House Gases
[3] Net Energy Balance, relates energy input and output throughout crop production and conversion to biofuel

that has caused so much global debate and attention on biofuels development in the recent past.

Biofuels were seen to offer the promise of numerous benefits related to energy security, economics and the environment (NIGAM 2011). First generation biofuels produced from conversion of plant starch, sugars, oils and to some extent animal fats, can be used in combustion engines with little or no modification, recycle atmospheric carbon dioxide thereby reducing the GHG related to fossil fuels.

The biofuel hype intensified at the turn of the 21st century with the EU leading the world by setting ambitious targets to reduce emissions from its energy sector especially for transportation. The challenge the EU faced was limited land needed to produce feed stocks for its biofuels since all their arable land is already over committed to produce food and feed intensively (WIESENTHAL, 2009). Africa is seen as the single largest potential for the production of bioenergy crops globally (AMIGUN, 2011). Southern Africa was identified as one of the regions that had the potential to produce energy crops for vegetable oil for EU market mainly because it is seen to have adequate arable land and low population density. EU Renewable Energy Directive (RED) set blending targets to increase the consumption of greener fuels. As a result, development aid programming re-aligned its focus to agriculture and renewable energy development and deployment in Sub-Saharan Africa. Investments were mobilised to avail funds to multi-national companies through various mechanism including CDM[4] to implement a private sector driven biofuels programme in Sub-Saharan Africa and Asia. This marked another generation of "land gold rush" by investors from OECD[5] countries to produce raw material needed for biofuels development.

Biofuels are projected to remain an important energy development target in many parts of the world even when depressed petroleum prices persist. However, potential impacts of large global expansion of biofuels on food production capacity and food security globally and per region or even country are hard to determine. It can either

[4] Clean Development Mechanism
[5] Organisation of Economic Cooperation and Development

be negative or positive depending on local conditions and choice of feedstock. It is generally accepted that the impact on net food producers and consumers in low-income countries (especially) require appropriate policies to reduce impacts to a minimal. This raises the question on whether it is possible to produce biofuels sustainably and to deliver the promises of eradicating extreme poverty and hunger by 2030 for the poor people especially in the global south (NAYLOR, 2007).

Opposition to first generation biofuels is generally assumed to be about the competition with food security (MOHR, 2013). To avert the "ugly" competition with food production, it became necessary to develop guiding principles to minimise or avoid negative impacts on the environment and food security in host countries. One such initiative was to create sustainability guidelines that followed an example of the palm oil and coffee protocols to develop principles to guide the development of sustainable biofuels RSB[6]. One guiding principle included preference of non-food crops like Jatropha and Palm oil that exhibit potential for multiple uses as a feedstock as opposed to primary food crops.

1.2 Rise and fall of Jatropha-based biofuels projects

Among oil bearing crops, Jatropha and palm oil were considered as crops that had the potential to meet the criteria of energy crops for biodiesel while sugarcane was considered as a viable option for bioethanol. Jatropha was considered "the miracle crop" at the time that could deliver on most promises of biofuels that included among other things (VON MALTITZ 2014; JONGSHAAP 2007; GLOBAL BIOENERGY PARTNERSHIP 2007; ACHTEN 2010):

- Increase energy security and hence economic stability
- Delivery of high-quality jobs in especially rural areas
- Increased farm incomes in rural areas;
- Mitigate against land degradation and desertification;
- Reduce GHG emissions without creating competition for food production.

[6] Round Table on Sustainable Biofuels: https://rsb.org/the-rsb-standard/

It was considered to be a robust alternative energy crop but despite all the promises, most Jatropha feedstock production projects in Sub-Saharan Africa failed miserably and have left many families and some ecosystems desperate (MALTITZ, 2014)**.** This disillusioned people and governments, pushing already those living below the poverty datum further into poverty and eroding in the process, their ability to basic necessities of life in the immediate future. Some governments in the SADC region (like in Namibia and Botswana) reacted by banning the implementation of Jatropha projects completely in target areas. Whether such decisions were taken after holistically assessing the reason(s) why the projects failed is still yet to be investigated.

1.3 Problem Statement and Hypothesis

When the biofuels agenda gained momentum globally, many SADC member states considered to implement biofuels programmes as they looked at the potential to diversify the agriculture sector and foster rural development in the region. Millions of SADC small holder farmers, who depend on seasonal agriculture, continue living in poverty due to limited access to both inputs and markets (TAKAVARASHA, 2005). Therefore, the main drivers of implementing biofuels programmes in the region included the following:

- Commercialisation of agriculture and diversification of the rural economy by linking farmers to the energy sector that could provide a lucrative market for their produce and therefore generate employment
- Foreign exchange savings through import substitution since most SADC member states are net importers of liquid fuel. The saved funds if utilised appropriately have potential to stimulate economic growth and poverty reduction
- Enhancement of energy security at local, national and regional level (in the transport sector mainly)
- Contribute to curbing of deforestation and degradation of the agricultural ecosystems by adopting non-food crops like Jatropha and non-cereal crops like palm oil

- Contribute to GHG (mainly CO_2) emissions reduction (especially for South Africa, being the largest emitter of CO_2 in Africa due to its coal-dominated electricity sector and large fleets of vehicles)

Several projects, driven mainly by foreign investors, were introduced and implemented in the region but (most if not all) failed to deliver on the promises and left many people desperate. This eroded the trust that governments had in biofuels significantly. As a result, many SADC countries condemned Jatropha-based biofuels and even pronounced measures to discourage the introduction of biofuels as they feared that it would impact negatively on food production, the environment, economy and the people. Many reasons have been advanced as to what led to the failure of the first attempts ranging from absence of policies to limited knowledge and local capacity to implement and manage a sustainable biofuels programme. The 2008-2009 food crises were triggered by biofuels as the global cereal supplies decreased due to diversion of cereal to biofuels especially in the USA and Canada and price speculation (MITCHELL[7] 2011 unpublished). The SADC grain focused in the same period reported an increase in total cereal production output across the SADC region (FAO 2010).

Most of the SADC member states' biophysical conditions are potentially suitable to grow most of the suggested feedstock crops as there seem to be a comparable abundant suitable land to grow both energy and food crops. This is true especially for Angola, DRC, Mozambique, Malawi, Tanzania and Zambia. Even though the SADC region has agricultural ecological conditions and adequate policy framework that can support most biofuels feedstock production, there is very little evidence to show on the ground in terms of projects except for the ethanol generation capacities and programme in Malawi, Mozambique, South Africa, and Zimbabwe. South Africa and Zambia have implemented biodiesel programmes but at limited scale.

[7] The report that Mitchell was doing for internal circulation leaked out causing a wave of panic and speculation that led to holding of cereal and banning export by some Asian countries. Personal communication

It is the absence of successful operational projects to demonstrate this potential and the presence of many failed field projects that motivated this work to be carried out and to a large extent influenced the hypothetical statement that:

"The SADC region possess adequate biophysical, socio-economic and political conditions to design and implement a sustainable biofuels value chain programme with insignificant (or none) negative impacts on food production, food security and to compromise the ability of the agricultural ecosystems to remain productive"

1.4 Aim of study

The main aim of this study is to contribute to the quest of finding possible solutions to a very complex problem of biofuels development and sustainability by evaluating the potentials, conditions and challenges of *Jatropha Curcas L* (in short JCL, herein referred to simply as Jatropha) based feedstock production systems in the SADC region. In particular, this work makes an effort to develop a conceptual evaluation framework and appropriate tools/methodology which can be used in assessing potentials, diversions and impacts of agro-based biofuels programmes at project, national and/or even sub continental-region levels.

1.4.1 Specific objectives

It is important to realise that most biofuels projects are first agriculture before they are anything else and therefore tend to be influenced by different agricultural related policies and physical local conditions. This fact, coupled with other global demands pressed on top additionally, means that it is almost impossible to rely on one method or approach to evaluate the sustainability of a Jatropha based biofuels programme. Therefore, a mixed methods approach is adopted in this study with specific objectives being to:

1. Empirically assess Jatropha as an energy crop in terms of its biophysical and agronomic demands including its carbon storage potential
2. Evaluate the bio-physical and agronomic conditions, potentials and constraints for biofuels development in SADC

3. Develop a conceptual evaluation framework for assessing biofuels diversions and its impacts on food production and sustainability
4. Conduct an evaluation of Jatropha projects using the framework to identify critical success/failure factors of selected case study projects in selected SADC countries
5. Document lessons and recommend key policy-based instruments and conditions for a sustainable biofuels programme based on the evaluation framework

1.5 Research questions

To tackle the above specific objectives, the study seeks to answer the following major questions:

1. Does Jatropha possess the robust attributes (biophysical and agronomical) which have been claimed in literature as a viable energy crop?
2. Does the SADC region have biophysical, agronomic and institutional conditions necessary to support for viable and sustainable biofuels programme?
3. Are the existing tools, methods and frameworks to evaluate sustainability of biofuels projects and programmes robust enough?
4. What factors contributed to the failure of many Jatropha projects in the selected countries in the SADC region?
5. If biofuel programmes and projects are to be promoted and implemented sustainably in the SADC region, what are the key factors and indicators that must be considered?

1.6 General Approach and methodology

Understanding the potential and constraints of developing sustainable biofuel value chains in general and in the SADC region (in particular), necessitates a wide range of approaches ranging from empirical field trials to understand the choice of feedstock, analysis and evaluation of biofuel feedstock development projects to assessing whether conditions exist to support such a programme. Therefore, a single method approach would be inadequate to comprehensively answer a multiple of convoluting questions.

A mixed methods research design is an approach to inquiry that combines (or associates) both qualitative and quantitative forms and involves philosophical assumptions that compels the research to collect and analyse both forms of data in a tandem so that the overall strength of the study is stronger than using either quantitative or qualitative approaches alone (CRESWELL 2007). In this study a mixed methods design was therefore adopted and applied.

1.6.1 Literature review on biofuels, development and sustainability

A literature excursion was undertaken to understand some historical nature and drivers of Jatropha based biofuels development and implication on sustainability as we know and apply the concept or term today. This included a thorough review of selected literature on biofuels development and its implications on food production, food security, the biophysical environment and potential as a climate change adaptation and/or mitigation mechanism. Different country institutional official reports and policies were consulted and analysed to determine whether the legal and institutional framework conditions to implement biofuels were present and adequate in the region at that time.

In addition, a review of various theoretical frameworks, concepts and tools for assessing sustainability in literature was done to evaluate the applicability of such to biofuels feedstock development programmes and projects. Government and NGO reports were also used to gauge the effectiveness of mechanism to ass sustainability of biofuels projects.

1.6.2 Biophysical and agronomic trials on Jatropha

The quantitative aspects of this approach involved conducting empirical on-the-farm experiments in carefully selected locations to determine the biophysical and agronomic characteristics of Jatropha as a plant and assess whether the various claims about it as found in literature has some basis to justify it as a *wonder* energy crop. This involved selecting wild trees, setting up of nurseries and trial plots in Namibia and

Zambia as semi-arid and semi-tropical regional representatives respectively to among others:

- determine its growth potential and yields under different field/farm conditions to understand and evaluate its agronomic demands
- quantify its biomass as this has bearing onto its health and carbon storage capacity
- Evaluate its robustness to arid and semi-arid conditions and assess availability of land using its potential optimum agro-climatic preference
- Evaluate its potential as an energy crop

1.6.3 Formal and informal Interviews

Parallel to physical trials on Jatropha, several interviews were conducted. The interviews, which were both formal (like questionnaires with experts and project proponents) and informal focus group discussions (like chatting with farmers and communities), were planned and conducted in a semi-structured fashion.

- Beneficiary stakeholders: ranging from peasant farmers, smallholder farmers, workers and community members at household level including traditional leaders in target project areas to assess if there was perceived as well as actual benefits, the impact on their productivity, incomes and food security
- Project proponents or implementers/managers: this followed a set of questions influenced by the production model adopted, size and any specific standards suggested by the implementers
- Expert Interviews: selected experts were interviewed based on the role they played or envisaged to play in the biofuels value chain especially in Zambia and Namibia. These included farmer/producer associations, professional bodies, NGO/CBO working in the sector
- Policy makers: biofuels are complex as they start as agriculture before they enter the energy sector value chain. It was therefore necessary to interview policy and regulatory bodies in the agriculture, energy and

environmental/natural resources management sectors and other dependent sectors

- In Malawi, interviews were limited to selected government officials in two key ministries, one key investor, one sugar plantation operator, and two experts. For Mozambique, notes from a stakeholders' workshop and selected meetings during a visit in 2009 were used in conjunction with available reviews and reports.

1.6.4 Meta evaluation of mega projects

The term 'meta-evaluation' was coined more than forty years ago by (MICHAEL SCRIVEN 1969). The term meta-evaluation refers to "evaluation of evaluations". They are concerned with bringing together the evidence from a range of sources and exploring implications for policy and practice. They overlap in purpose and methods with broad-based systematic mixed-methods reviews ('synthesis studies') and methods for testing the evidence for policy programmes (GOUGH AND MARTIN, 2012).

Therefore, historically, Meta evaluation methods were considered when identifying relevant primary research studies, assessing quality, relevance and techniques of approach by bringing together interpretation of empirical data collected with field visit observations to openly discuss and communicate with the target objective. In this study, Meta evaluations were done in Namibia and Zambia and involved:

- **Review of documentation** relevant to the project to understand what motivations and criteria were used to influence decision to implement the project in question
- **Roundtable discussion** mainly with the beneficiary farmers to gauge their experience on "Jatropha" in order to examine the strengths and weaknesses of the impacts of biofuel on their livelihoods
- **Interviews and consultation with different stakeholders in biofuels and related industry**: this was designed with a specific purpose of evaluating public and private perceptions towards biofuels and their role in the bio-energy economy. It involved talking to those directly involved in the biofuels sector in general and assesses in more detail the strengths and weaknesses of a national

biofuels programme. This generated data that was used to evaluate stakeholders and experts' opinion in study countries and later used to develop a generalised conceptual evaluation framework.

1.7 Data analysis and diversion-based evaluation of biofuels projects for sustainability

The first step in evaluation of biofuels projects required developing and implementing a multi-scale diversion-based evaluation framework. This involved identification and definition of clear criteria and principle indicators that can later be used to analyse each project at different scales, with a local project site perspective first. The obtained results per project are then comparatively analysed at national level to identify critical common success or failure factors that could form an aggregated evaluation framework of biofuels at national level. Such results are then further compared between study countries, aggregated and analysed in terms of key impacts (positive or negative) on food production, food security and sustainability at SADC regional level.

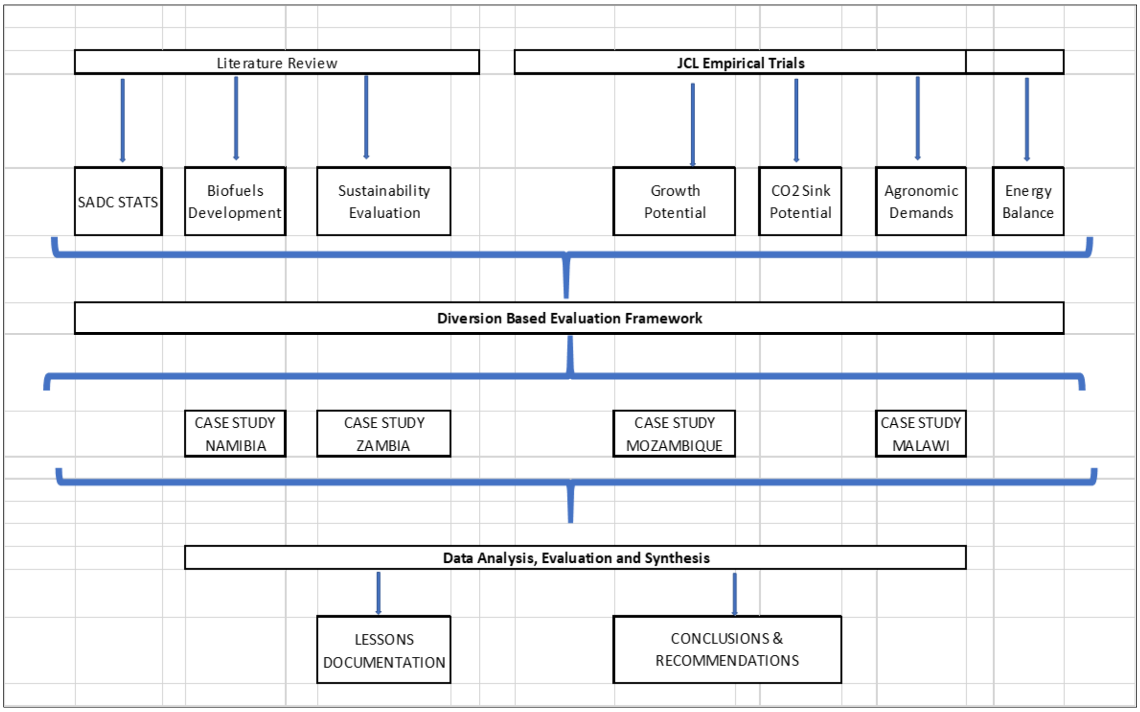

Figure 1-1: Summary of the methodology: (Author's own, 2015)

1.8 Description and justification of study Area

The Southern African Development Community (SADC) is one of the oldest regional socio-economic communities in Africa with 16-member states of a very wide range of geographic, socio-economic and ecological characteristics. SADC evolved from the Front-line Member States[8] which after total political independence of the region became Southern African Development Coordination Conference (SADCC), and after South Africa joined became become an economic community. SADC headquarters and secretariat is located in Gaborone, Botswana.

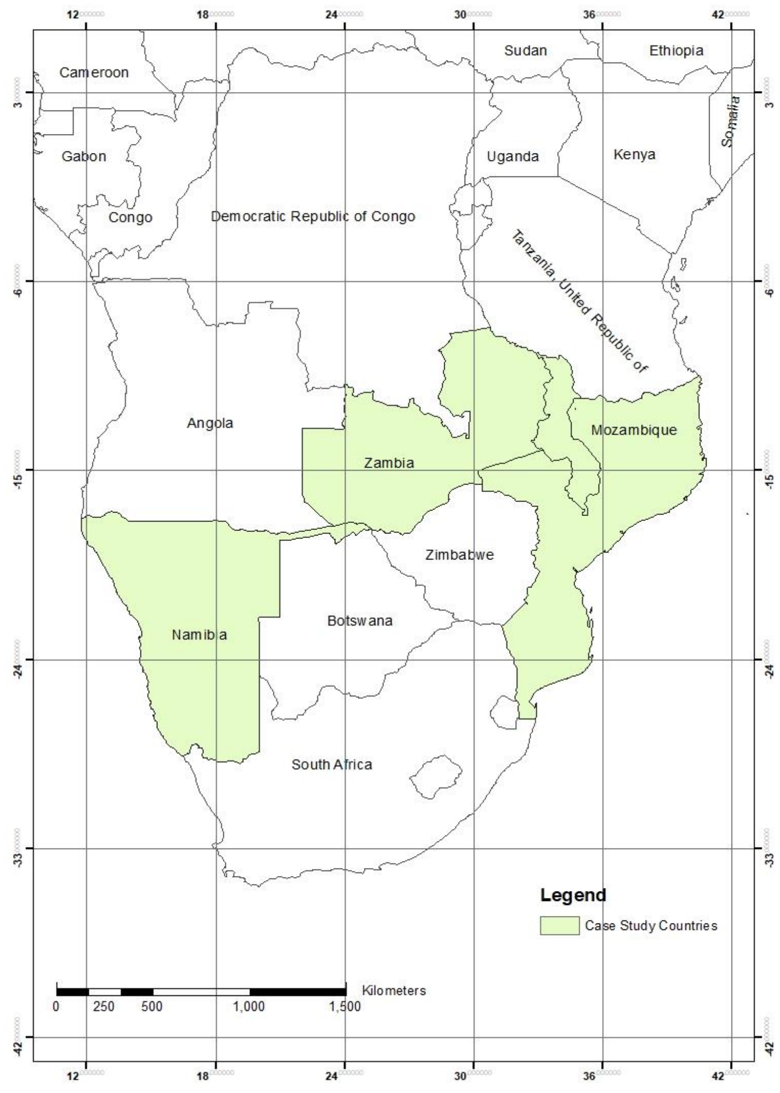

Figure 1-2: Map of SADC Region Showing Study Countries: (Source: Author's own)

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[8] Front-line States was a diplomatic coalition of independent Southern African countries (Angola, Botswana, Mozambique, Tanzania and Zimbabwe) which emerged in order to crisis-manage the liberation wars in the region

With a population of about 305 million and projected to reach 388 million in 2025, the SADC accounts for about 32% of total Sub-Saharan Africa population and three countries (South Africa, Tanzania and the DRC) accounting for 60 %. It has an average annual population growth 1.9 % (ranging from 0.09 % for Mauritius up to 3.09 % for Angola) and a population density of 30 people per square km (ranging from 2.8 in Namibia to 619 for Mauritius), putting SADC among the lowest densely populated regions in the world. This is mainly because large areas of the southern half are arid or semi-arid and are therefore unable to support intensive agriculture that promotes dense settlements. SADC has an urban migration challenge with an average of about 35 % living in urban centres (SADC Year Book 2015).

1.8.1 Jatropha Development in the SADC Region

SADC region biofuels programme took off as the biofuels hype intensified globally with international companies led by British Petroleum (BP), D1 Oil, LLD, MAN, Petrobas, BERL, Oval Biofuels, Copperbelt Energy Company, Southern Biopower and many others. Some applied for long term land leases to grow Jatropha in Malawi, Mozambique and Zambia while Namibia had limited initiatives led by Prime Investments and Le Leviev Diamonds (LLD) Biofuels with a few on-site farm experiments. Jatropha was targeted as an energy crop based on the belief of its robust diverse attributes of an oil-bearing plant. However, most projects did not deliver the promises and performed below expectations. This led to frustrations on the part of investors and with the 2008/09 financial crisis, several investors decided to withdraw from these projects leaving massive gap in biofuels production with many stakeholders and local people disillusioned

The four SADC countries were therefore chosen as representative sites to evaluate Jatropha based biofuels development, its potential and constraints in terms of energy provision, enhancing food security and sustainability. Zambia and Mozambique were hot spots for Jatropha based projects while Namibia was selected specially to look at the potentials and constraints of Jatropha in arid and semi-arid environments. Malawi is an agriculture-based economy with a long history of ethanol production. It has sustained a 10 % blend with gasoline (i.e. petrol) since 1982 (AMIGUN, 2011) and hence provided a good basis to analyse the biofuel and food security debate.

Despite the promise of biofuels especially from Jatropha, most projects in the SADC region failed. Since most people in the SADC region depend on agriculture for food and employment, it is important to look at why Jatropha based biofuels development failed and analyse the macro and micro impacts at national level and on the local people respectively that this may have in terms of food production, food security and sustainability.

1.9 Thesis Structure

This thesis is structured in seven chapters, beginning with this introductory chapter, **Chapter 1**. It begins with the drivers of developing Jatropha plantations in the SADC region as one of the feedstock options for biodiesel. Based on the identified problem statement, the chapter outlines the objectives, research questions and describes the general approach and methodology including the study area.

Chapter 2 goes into the details of what drove the choice and development of Jatropha plantations in the SADC and end with a short analysis of the implications of the expansion of Jatropha-based biofuels value chains in terms of food security.

Chapter 3 is the literature excursion on the theoretical concepts related to sustainability, food security and tools that are commonly used to assess and evaluate projects in terms of sustainability. This motivated the author to develop and test the effectives of diversion-based evaluation framework of Jatropha-based biofuels value chains.

In order to evaluate the sustainability of Jatropha-based biofuels value chain, it was important to first understand and validated some of the claims about Jatropha's potential as an energy crop. Therefore, Chapter 4 concentrates on the empirical experiments about Jatropha as a plant.

Chapter 5 is about the case studies in three different countries namely Malawi, Namibia and Zambia. Each country is briefly described with a focus on agricultural potential and the ability to support Jatropha development. Selected Jatropha projects are briefly analysed and evaluated using the diversion-based evaluation framework against sustainability criteria and food security.

Chapter 6 is a synthesis of the findings and discusses the implications of the results of evaluation of Jatropha biofuels value chains in the SADC countries. It tries to answer the question whether the SADC region has enough arable land, biophysical capacity and a conducive framework to accommodate an expanded biofuels programme. It concludes with some policy suggestions on how to avoid resource diversions and its potential (negative) impacts food production, food security and sustainability.

Chapter 7 is the concluding chapter of this thesis. It summarises the study by checking whether the study met its intended objectives or not. It then ends with the key debate on the triple dilemna (i.e. trilemma) of food, energy and climate change. It also makes recommendation on further studies that may be necessary to unpack this global challenge.

2 Jatropha-based Biofuels Development

According to the UN FAO, biofuels are energy carriers that store energy derived from biomass and bioenergy is the final product. This definition gives a universal understanding that biofuels include both solid forms (such as firewood, charcoal, wood chips, pallets, cow dung) and liquid or gaseous fuels obtained via the processing of biomass from food and oil.

However, it is increasingly becoming acceptable in literature that biofuels in the recent past has come to refer to more modern liquid fuels that are derived through process of energy and food crops while bioenergy is mainly referred to traditional use of biomass for energy. The Roundtable on Sustainable Biofuels (RSB)[9] has also adopted the term biofuels to refer to liquid or gaseous fuels for transportation derived from processing of biomass and this study has adopted this biofuels definition.

2.1 Global drivers of biofuels development programmes

Historically biofuels development was driven by the need to find alternative markets for the surplus agricultural outputs so that the farmers can be kept on the land to continue providing the much-needed food for national food security. This is because the agricultural sector fails to compete with other lucrative industries in terms of profit and return on investment. High crude prices of the 1970 driven by disruption of supplies from the oil rich countries in the Middle East renewed this trend with Brazil leading in formulation and implementation of a national biofuels programme (REN21, 2012).The USA followed in the 80s and this influenced Malawi to be become the first country in Africa followed by Zimbabwe to embark on a national biofuel programme. Europe followed suit in the 90s and quickly became a leader in biodiesel production.

Biofuels were heralded in the early-to-mid-2000s as an important strategy for reducing reliance on fossil fuels and mitigate the associated GHG impacts. In national context, it was perceived as a silver bullet able to provide sustainable supply of fuel since feedstock can be grown with numerous ancillary potential benefits economic nature and poverty reduction (GASPARATOS, 2015).

[9] Roundtable on Sustainable Biofuels, based in Switzerland

The rapid increase in greenhouse gas (GHG) emissions due to heavy reliance on fossil fuels and an ever-expanding use of motor vehicles, trains, ships and aircrafts for mobility has led to negative impacts on global warming. This great concern of increase in global temperatures led to various initiatives to curb GHG emissions and biofuels development was identified to possess immense potential to achieve targets set by different economic blocks. In 2005 the UNCTAD launched the biofuels development initiative in Paris with a primary objective of helping developing countries to build capacity in the production, use and trade of biofuels resources and technologies together with an expanded awareness of the public and private sectors on the challenges and opportunities of increased biofuels production and use.

Since then a lot of countries in different regions have embraced biofuels initiatives as can be seen in figure 2.1 below. In the EU, the USA, Canada and China, use of oil crops to biodiesel increased from below 1 million tons in 1990 to over 1.8 million tons in 2004 (REN21 2012).

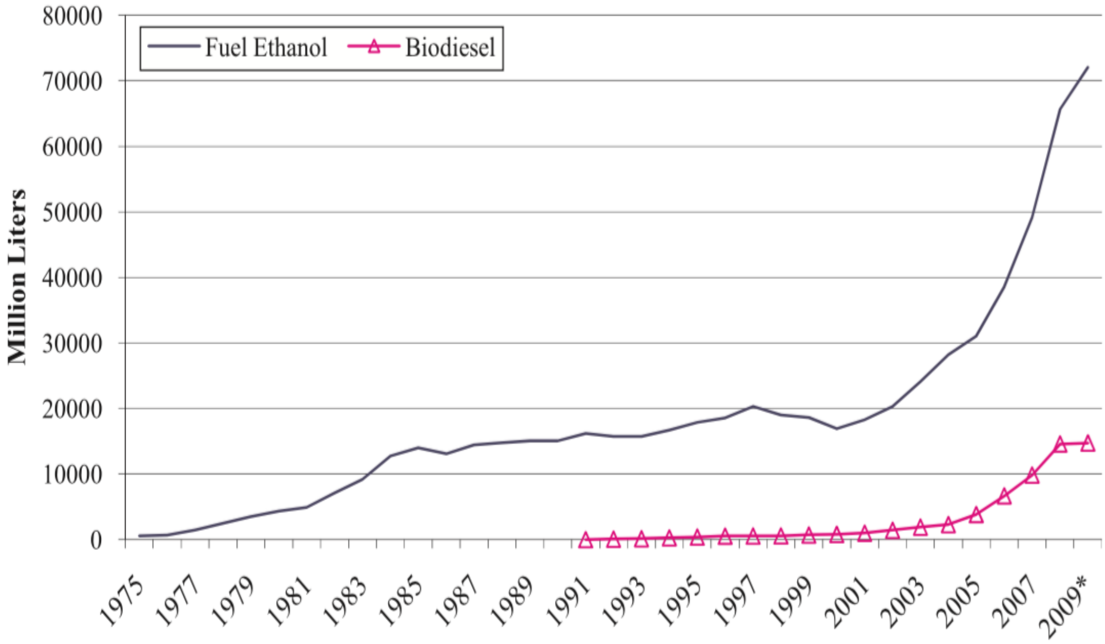

Figure 2-1: World annual ethanol and biodiesel production 1975-2005: (SORDA 2010)

2.2 Global drivers of Jatropha development

The appetite to develop biofuels from non-food crops helped Jatropha to become an example of a novel crop that could offer the benefits of biofuels from degraded land in semi-arid regions with little or no negative implications on food production systems, soil fertility and carbon stocks (Leuphana 2012). It was hailed as an alternative crop that had potential to deliver jobs in the rural areas and contribute to development targets of mainly developing countries. Some governments launched programmes to support Jatropha cultivation across the globe with China and India in the lead. Development Aid also embraced this and rolled out programmes to support small-scale farmers especially in sub-Saharan Africa (ACHTEN 2009).

A study by GEXSI (2008) reported that some 242 Jatropha projects with a total area of 900 000 hectares of land under Jatropha cultivation were present. 84% of these projects were implemented in Asia with some 120 000 hectares (or 12%) planted in southern Africa mainly Madagascar, Mozambique and Zambia. The projected expansion of Jatropha led to a new scramble for land by multinational corporates such that the term “land grab” resurfaced strongly especially among NGOs to save the vulnerable farmers from losing their land on which they depend on for practice subsistence farming.

The table below shows the size of Jatropha projects in terms of total area planted in selected countries in Africa and Asia by 2011. This shows how rapidly countries embraced the development of Jatropha plantations for biofuels. However, the rate of development in Africa was far behind compared to that in Asia.

Table 2-1: Jatropha cultivation for selected countries: (Author's own, data LEUPHANA 2012)

Country	**Jatropha (Ha)**
China	274 559
India	265 422
Indonesia	256 545
Ethiopia	20 000
Ghana	13 000
Madagascar	8 300
Mali	8 000
Tanzania	6 926
Mozambique	3 585
Zambia	2 789
Malawi	350

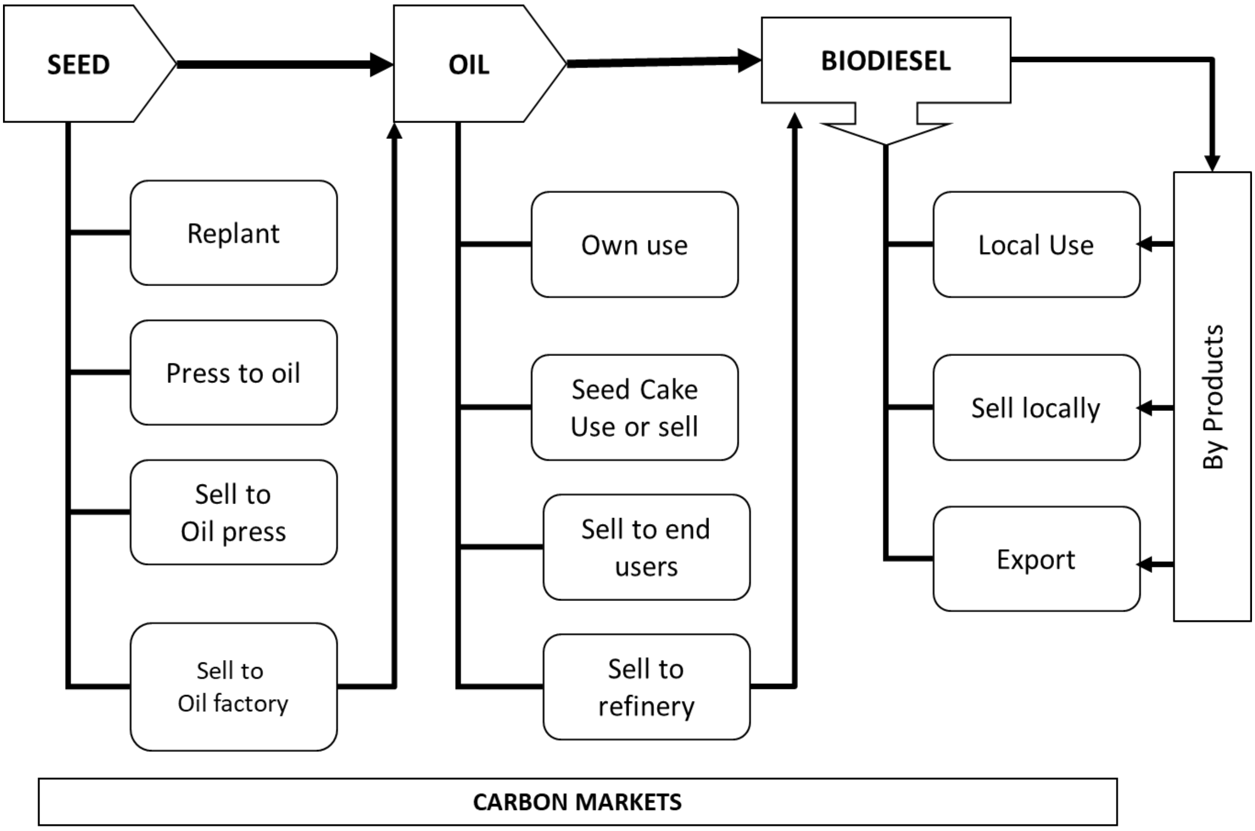

Figure 2-2: Jatropha biodiesel value Chain (Author's own)

2.3 Jatropha Development in the SADC region

The sections above in this chapter highlighted global drivers for Jatropha-based biofuels development. This section focuses on the SADC region as an economic block, highlighting in broader terms, the regional development imperatives that provided the reason to investigate the potential of biofuels as a strategy to enhance and modernise agriculture and accelerate rural development. It also discusses the biofuel crop production potential in relation to liquid fuel demand, land availability and climate change related implications.

A study was commissioned by the SADC secretariat in August 2005 after the Joint meeting of SADC senior officials in charge of food and agriculture, natural resources, infrastructure and services held in Gaborone in 2004. The joint meeting agreed that biofuels initiative presented an opportunity for the region to produce its own fuel from renewable resources. The main objective of the study was to assess the feasibility for production and utilisation of biofuels in the SADC region.

By 2012, almost every SADC country had some form of Jatropha cultivation either at project implementation stage or as field trial to assess its potential.

2.3.1 SADC Agricultural development: Constraints and Climate Change Implications

The agriculture sector is a prominent sector in the SADC regional economy, contributing between 4 % and 27 % of GDP in different member states. About 70% of the population in the region depends on agriculture for food, income and employment. It is also a major source of foreign currency earnings for several countries with Malawi almost entirely dependent on it for its foreign income (more than 90 %). It also contributes to 66 % of intra-regional trade value (SADC RAP REPORT 2011).

However, the SADC agriculture sector suffers from major constraints such as limited access to inputs, technology, finance and markets. These have been identified as major barriers to agricultural development and attainment of regional food security. For land locked countries like Botswana Malawi, Zambia and Zimbabwe, the cost of production and marketing is constrained by the large distances to major ports for importation of fertilizers and export of produce. In order to address this, SADC developed some legally binding instruments within the Regional Agricultural Policy (RAP) framework to stimulate agricultural development and food security.

In terms climate change implications, In Southern Africa, studies have indicated that the climate changed during the 20th century with mean annual temperature rising by 0.5 ^{o}C, extent and intensity of droughts greater and occurrence of heavy rainfall events on the increase in several countries. It is predicted that the region may experience a mean annual temperature rise of between 1.9 ^{o}C and 4.8 ^{o}C by between 2080 and 2099 (CHRISTENSEN 2007). These trends are anticipated to have a greater impact on a variety of economic sectors especially agriculture that is dependent on the amount rainfall**.**

The region faces similar key challenges like the rest of SSA that include access to modern energy, prevalent poor health conditions of its people, degrading environment, energy security, food security, poor infrastructure and finance. More than half a billion people in SSA rely on solid biomass to meet their daily energy needs for cooking, heating and lighting, which is labour intensive, polluting, destructive to the environment and inefficient (CHAKAUYA, 2009).

2.3.2 Drivers of Biofuels in SADC region

At global level, the main driver for biofuel development is seen as a one of the strategies to reduce reliance of fossil fuel and mitigate against its impacts on carbon stocks. Although this aspect is important, it was not the main driver for biofuels development in the SADC region. The main drivers for the SADC region, according the SADC Biofuels Development Initiative are:

- Creation of rural employment and diversification of the rural economy
- Enhancement of energy supply and security especially for the transport sector since the region
- Saving of foreign exchange since, although has petroleum producing member countries, is a net importer of petroleum and its products mainly from Arab countries
- Creation of a huge market for increased agricultural productivity
- Contribute to reduction of deforestation and desertification, thereby enhancing ecological quality and eco-services
- Contribute to the global agenda of reducing GHG and other emissions from vehicles

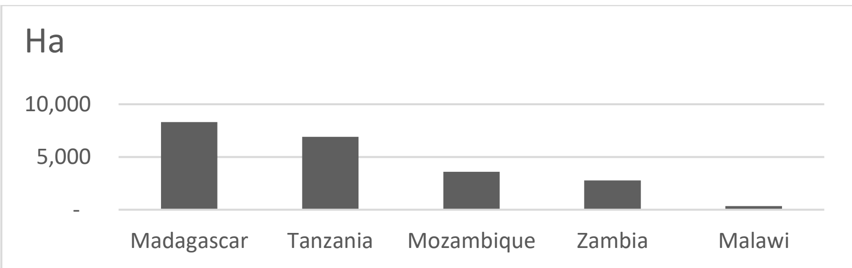

Figure 2-3: Jatropha cultivation (Ha) in selected SADC countries: (Author's own, data LEUPHANA 2012)

2.4 Concluding remarks: Food security and biofuels in the SADC region

Most SADC countries are endowed with an acceptable amount arable land indicating a good potential for agricultural development. Despite having an enormous potential, the region's agriculture sector suffers from many ills such as limited access to means of production and markets and climate change related impacts.

Regarding food production, southern Africa suffers a lot from the episodes of El Niño because small-scale farmers are entirely rain-dependent, making production highly susceptible to rainfall variations. El Niño episodes have a correlation with reduced maize outputs but the magnitude of this is not homogeneous across the countries. The frequency of negative shocks on production during El Niño has observed in South Africa, Swaziland (now eSwatini) and Zimbabwe with Angola, Madagascar, Malawi and Namibia registered low recurrent of loss of production. For example, in 2015, maize production declined by 27% on account of adverse weather leading to high maize prices between October and November to be well above the level in the previous years.

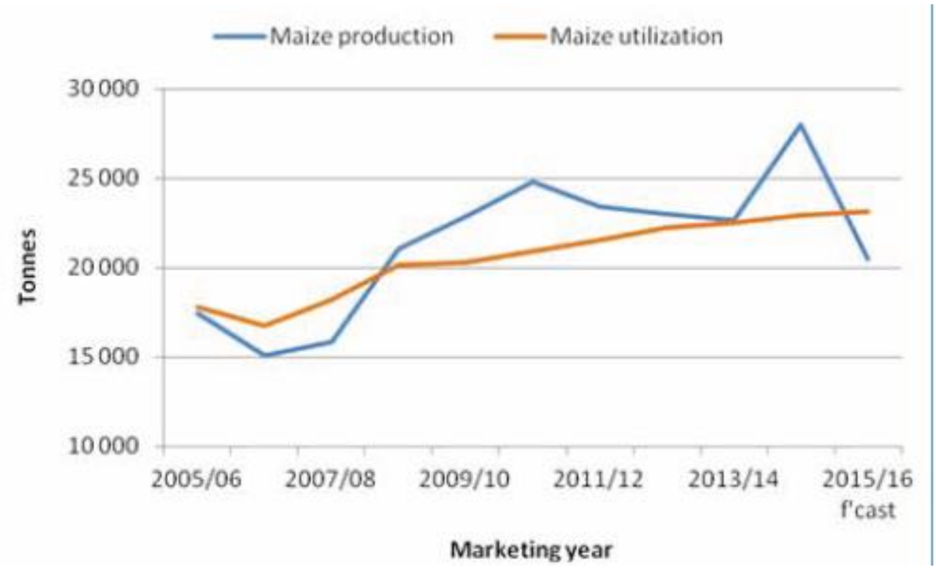

Figure 2-4: Southern Africa cereal production and utilisation (FAO 2015)

Despite the availability of arable land for food production and biofuels, the SADC region suffers from food insecurity induced by adverse weather linked to climate change. Table 2-2 shows the number of people considered to be food insecure in the SADC region in 2014/15 marketing season. In this review period, production of maize, which is the stable food of the region, was well above 20 million metric tonnes.

Table 2-2: SADC food insecure population 2013 -2015: (Author's own, data FAO 2015)

Country	**2013/14 ('000)**	**2014/15 ('000)**
Angola	700	No data
Botswana	No data	15
Lesotho	223	
Malawi	1 462	640
Mozambique	212	150
Namibia	779	118
Swaziland[10]	290	223
Zambia	209	351
Zimbabwe	2 207	565

This indicates that food security must be considered at local level as production does not necessarily translate into a food secure region. Namibia suffered the worst drought during 2013-14 season and over 30% of its population needed food relief.

The consequence of this is that any development that is agriculture based need to be assessed against the potential of causing further constraints on the production of cereal crops (maize in particular) and food security. Non-food biofuel crops are not spared from this assessment even if they may not necessarily be responsible for low food production and high prices. Given this, it is important that cultivating energy crops must not lead to an increase in food insecurity in the region.

[10] Swaziland name was changed to eSwatini (meaning land of the Swazis) in 2018.

3 Diversion-based conceptual framework for evaluation of Jatropha value chains

3.1 Key concepts and theories

Before digging into the various aspects of sustainability and related evaluation frameworks and tools, it is imperative to provide clarity of the terms *assessment and evaluation* and provide the evolution of the concepts of *"sustainability"* itself or its preferred cousin *"sustainable development"* and *"food security"* as a sustainable development concern.

The idea of *sustainability* is both very ancient and recent. Before the modern era, most cultures in Southern Africa, aimed for stability and continuity of their existence, except maybe those of elites devoted to conquest. Their gods encouraged humility, and their elders stressed respect for tradition. The change happened, but it was never desired nor sought. People thought that innovation was most likely going to bring peril than progress and even mere curiosity could open a Pandora box of trouble. However, as a dominant concern, it was gradually abandoned over the last few hundred years in favour of progress through industrial, technological and economic advancement (GIBSON, 2005).

Faster economic growth through a self-adjusting positive market mechanism was promoted and seen to be able to guarantee development and progress to eliminate poverty and inequalities. However, there is overwhelming evidence that economic growth has failed to deliver the benefits where they are most needed and that it was destroying its own foundations on its own peril.

Costs and limits to growth, the overwhelming evidence of the effects of exponential economic growth on resources and climate change compelled the emergent of the term *sustainability* in the 70s after the UN 1972 Stockholm Conference on the Human Environments. The resolution, made by the World Commission on Environment and Development, led by Norwegian Prime Minister Gro Harlem Brundtland, (hence the famous name "the Brundtland Commission") proposed that there was another way of attaining development. Resource limitation and emission constraints created many crises since 1972, excited the media, attracted public attention and aroused politicians alike (MEADOWS 2005).

The term sustainable development was born out of all the Brundtland commission and could moderate this unchecked economic growth and save the planet from total collapse. Sustainable development gained preference to "Sustainability" as the latter term was believed to be a way of only bridging the gap between the promoters of economic progress through growth and those critics of it (GIBSON 2005).

At the dawn of the millennium, the concept "sustainability" had been widely adopted and embraced by most governments and multi-national conglomerates. The Agenda 21 adopted and operationalised the term "sustainable development". It has been translated into many national development programmes to curb the overwhelming continued degradation of ecosystems, and natural resources and the gap between the rich and the poor.

However, one fact is clear: sustainability as an idea, term or concept is real and will continue to spread and would be boosted even more by the 17 "Sustainable Development Goals" (SDGs) as part of the 2030 Agenda for Sustainable Development adopted by world leaders at a historic United Nations Summit in September 2015 (UN 2017).

3.1.1 Defining sustainability and sustainable[11] development

Robert M. Solow wrote: "If sustainability is anything more than a slogan or expression of emotion, it must amount to an injunction to preserve productive capacity for the indefinite future" (SOLOW, 1992).

Sustainability as a theme or concept itself poses a potent challenge to conventional thinking about how we do things. As a result, it is impossible to define sustainability in absolute terms as it meant and continue to mean different things in different contexts to different people and nations across the globe.

[11] The Oxford English Dictionary defines *sustainable* as "capable of being upheld; maintainable, "and to *sustain* as "to keep in a person, community etc. from failing or giving away; to keep in being, to maintain at proper level; to support life in; to support life, nature etc. with needs."

Historically the term sustainability was a very conservative one and was concerned with the maintenance of social order and ecological viability. It was applied in the context of sustaining customary or traditional life services, the stability of communities and continuity of their well-being (Ike, 1984). Today the situation is different in this consumption driven society and so sustainability has a completely different face.

The sustainability debate has been greatly influenced by previous division in the environmental movement between anthropocentric and non-anthropocentric worldviews (Seghesso 2009; citing Pepper 1996). The former is based exclusively on human-related values and considers the welfare of humankind as the ultimate driver for defining policies related to the environment. Non-anthropocentric on the other hand rejects the idea that nature has value "only because, and insofar as, it directly and indirectly, serves human interests (Seghesso 2009, citing McShane 2007).

Although sustainability is an ancient concept, for many people it is still a new idea of looking at the way we do things, an idea which many still have not grasped fully, and if so, do not know how it can manifest itself. Contemporarily, sustainability as a concept was originally coined in forestry, where it meant never harvesting more than what the forest can yield in terms of new growth (Wiersum, 1995). In recent years, sustainability has become a popular word in environmental policy and research arena. It is increasingly viewed as a desired goal of development and environmental management, and the term is often used by institutions and individuals that are concerned with the relationships between humans and the global environment (Liverman, Becky, Mark, & Merideth, 1987).

It can be defined in many ways depending on what the contexts and intentions are. To a business person, sustainability may mean the ability to run the business profitably perpetually with ability to grow it to maximise the return on investment. To a farmer, it may mean that the land on which farming is done is able to provide the same capability to sustain farming activities for a long time to come. In simplest general terms it is easier to say a sustainable society is that one that can persist with the "give-me-what-I-want-to-enjoy-forever" theme over generations.

The generally internationally acceptable formal definition of a sustainable society is the one that is derived from the famous memorable words quoted in the **Brundtland Commission** that:

"A sustainable society is one that meets the needs of the present without compromising the ability of future generations (or societies) to meet their own needs".

You can see immediately even from this definition that it is about ***sustaining society's lifestyles hidden in need*** without mortgaging future generations' ability to do so. This is a tall order to get all we want and at the same time keep some for our future generation. Is this what sustainability could be or should be or aim to be all about?

According to Holling's argument, sustainability is the capacity to create, test and maintain adaptive capability and that development is the process of creating, testing and maintaining opportunity. Thus, sustainable development refers to the goal of fostering adaptive capabilities and creating opportunities (HOLLING, 2001). A common criticism of the sustainability field is that definitions are vague and that the vast number of different tools, methods and concepts leads to confusion (Missimer, 2015).

In the context of this work, it is important to seek a definition that would in one way or the other encompass the idea of ***resilience of biophysical, economic, social and cultural systems*** to support life amid change, a phenomenon that seems to be the only constant we cannot avoid today. Resilience is argued to be a fundamental characteristic of both human and natural systems (GUNDERSON 2001) and promoting and strengthening resilience is seen to be a crucial component to attain sustainability of systems.

Therefore, the following working definition is offered in context of this study:

Sustainability is the ability of a system or systems to adapt and withstand change (positive or negative, local or global in nature) in order to maintain its (system or systems) ability to provide services or benefits as defined by current target beneficiaries with minimal or no detrimental impacts on the system's ability to provide similar or better services in future.

In many definitions, sustainability has been focused on what humans can derive from nature or system but notice in this definition that object of sustainability is *not the society but the system (or systems) itself (or themselves)*. It means a particular system can be seen to be sustainable even when humans drive no benefits from it. This is important!

Once sustainability is focused on the ability of a system to provide goods and services to current generation (without compromising the ability of the future generation to have a better future), the term sustainability translates quickly into sustainable development. Although sustainable development seems to be better understood and translated into plans, programmes and projects, the term is increasingly also regarded as internally self-contradictory (an oxymoron) or at best, plagued by ambitious or distorted definitions as well (JOHNSTON, EVERARD, SANTILLO, & ROBER, 2007). The consequence of this is that the implementation of so-called sustainable development projects has to some extent also not yielded sustainable results.

In the context of biofuels and food security, sustainability (or better still sustainable biofuels systems) would therefore imply that biofuel production systems and value chains are designed and implemented in such a way that they have the ability to adapt and withstand (or be resilient to) changes (due to climate, environmental, economic, social or cultural related changes) and maintain their productivity to provide the needed liquid fuel and its added benefits now and in the future with minimal or no negative impacts on the system itself and or food security.

3.1.2 Dimensions of Sustainability

According to SEGHEZZO (2009), sustainability is the conceptual framework within which the territorial, temporal, and personal aspects of development can be openly discussed. He proposed a triangle formed by place, permanence and persons with five dimensions that opposed the people-planet-profit *sustainable development* model adopted by the WCED 1987.

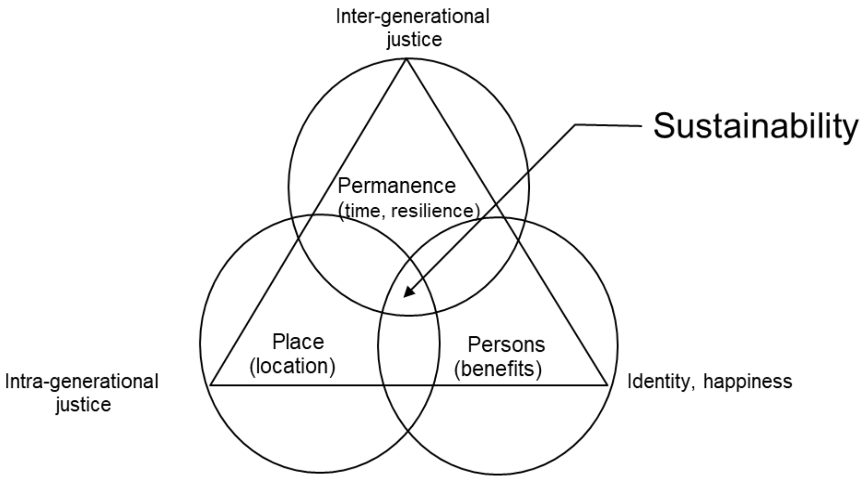

Figure 3-1: The five-dimensional sustainability 3Ps triangle: (SEGHEZZO, 2009)

This five-dimensional sustainability model (5DSM) model opposes the notion that for sustainable development to be attained, environmental and social implications of economic growth must be integrated in the decision-making process (SEGHEZZO 2009). He argues that:

- Place (i.e. location), is a function of physical, geographical and cultural constructed environment where people live and interact
- Permanence is not only a mere maintenance of present conditions but includes changes and improvements that could bring intra-and inter-generational justices
- Persons' are not necessarily limited to direct effects but includes values and that of those around and would be around the place of activity in future and how they would be affected as well. Personal happiness of individuals and subjective well-being must be connected to economic wealth, environmental quality and social justice and therefore must be considered as important aspects of sustainability.

The 5DSM presents an opportunity to look at sustainability wholistically as it includes the aspects of a three-dimensional location, time in terms of how resilient an activity at a particular location is and the benefits that people can derive from such an activity at that location. This extended five-dimensional sustainability model is adopted for the purpose of this study.

3.2 Food security

Food security a concept, it can be traced back to the mid-1970s amid the discussion of international food problems at the time of the global food crisis (FAO 2003). The initial focus during this period was the volume (linked to production) and stability (linked to storage and distribution) of food supplies.

However, the technical successes registered by the green revolution did not automatically and rapidly lead to dramatic reductions in poverty and levels of malnutrition. That means adequate food supply does not necessarily lead to a state of being food secure. As a result, and amid global food crisis, discussions arose as to "what does it mean to be food secure" is.

The 1996 World Food Summit adopted a more complex and internationally accepted definition that:

"Food security at individual, household, national, regional and global level is (achieved) when people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life" (FAO 1996).

In this definition, food security is implied to be at family level with individual members as the focus. Therefore, by implication, any project that has potential to contribute (positively or negatively) to food security raises attention of local, national and international stakeholders.

3.2.1 Dimensions of Food security

Food security is a multi-dimensional concept that manifests itself in numerous physical conditions resulting from multiple causes. The 1996 World Food Summit definition, food security is both an issue of supply and utilisation of that food supply and has four dimensions, namely:

- Availability: a function of food production, stock levels and net trade in food commodities. It includes the quantity, quality and diversity of food

- Access: which is the ability of people to access the available food to meet their minimum food requirement. The indicators for this can include physical access which is be dependent on food prices and infrastructure
- Utilization: which is the ability of people to process the food in such a way that it can meet the nutritional value required for a healthy life. It includes all variables that determine the ability to utilise the food such as access to water and energy.
- Stability: this is the measure of exposure to food security risks and the incidences of shocks to food security. It is affected by many variables ranging from availability of arable land, food imports to political stability and absence of violence.
- Sovereignty: places at the centre the issue of *food security as a human right* for communities to control the way they produce, trade and utilize food. This dimension

3.2.2 Sustainable biofuels value chains

Having defined sustainability, it is important to link this concept to value chain since the sustainability of biofuels will rely heavily on how sustainable the value chain for the same is.

The concept of value chains has established itself as one of the main paradigms in development thinking and practice. This has been accompanied by rapid increase in literature dedicated to all aspects of value chains, including analysis, selection, development and implementation (FAO 2014).

Since Jatropha-based biofuels value chain begins with farming, this work adopted the concept of sustainable food value chains (SFVC) framework as a basis of understanding the notion of sustainable biofuels value chains. In this framework, four core functions (or links) are distinguished and these are: production (in this case farming), aggregation, processing and distribution. At the core of such a framework is its governance structure that acts as an enabler of the value chain. Governance provides mechanism to create linkages between all actors horizontally and vertically.

A sustainable biofuels value chain is one in which the four core functions (production, aggregation, processing and distribution) are design, implemented and coordinated in such a way that they function to enhance value at each stage for the local producers, the society that may rely on them but without causing permanent biophysical degradation.

Understanding Jatropha biofuels value chain requires an understanding of the complexity of the environment (both biophysical and socio-economic) in which they are designed and implemented. This study focused on those subtle and yet significant diversions that could lead to destabilisation of one or more pillars of a biofuels value chain.

3.2.3 Biofuels value chain expansion and food security

The world experienced a sharp increase food prices and volatility between 2007 and 2008. Despite the differences in opinions and approaches to determine what led to this, many studies recognised that increase biofuels production and demand was one of the major drivers of food prices globally. However, the contribution of biofuel demand and production to increased food prices in terms of percentage was difficult to determine[12] (MITCHEL 2008, unpub). Therefore, it is accepted in the scientific and development community that biofuel expansion can lead to increase in food prices that limit both supply and access to food by many poor people.

About 70 % of the people in sub-Saharan Africa depend on agriculture and other natural resources for its livelihood and income (FAN 2008). Most of these are smallholders with 69 % of the farms being smaller than 2 ha and a mean farm size of

[12] The IMF estimated the increased demand for biofuels account for 70 % increase in maize prices and 40 % in soy bean prices (LIPSKY 2008) while Collins (2008) used a simulation and arrived at 60 % in maize prices from 2006 to 2008 could have been due to ethanol production.

2.4 ha (Eastwood 2010). Access to food and income is directly dependent on the quantity and quality of food crop production for most of these rural households and therefore, access to agriculture land is crucial for rural food security. Large-scale land investments for the expansion of biofuels production using agriculture land has direct implication on food production, food security and rural livelihoods. Securing access to productive land by rural people should not be compromised at all cost as it has potential to affect all four dimensions of food security.

With evident increase in adverse weather incidences and natural disasters, careful planning of large-scale land investments at national and local level is a pre-requisite to avoid devastating impact on rural livelihoods and by implication food security.

Another factor that need to be considered is the limited access to sustainable energy supply for domestic use and agriculture in rural areas. About 50% of the world's population rely on wood-based biomass energy for domestic needs with majority of these being in sub-Saharan Africa where 81% of its people depend entirely on wood fuel (THE WORLD BANK 2011). This makes consumption of wood fuel a major contributor to deforestation, loss of carbon stock and GHG emissions (FAO 2010). The quest to provide alternative energy, including modern biofuels, is an urgent matter for planning and deployment of energy systems in rural areas. Sustainable biofuels present an opportunity to reduce dependence on wood fuel in sub-Saharan Africa but require appropriate policy interventions and adequate monitoring.

3.3 Theory-driven evaluation

Before defining and describing the diversion-based evaluation framework, it is important to look at the two terms: evaluation and assessment and the theories of evaluation as a method or tool.

Assessment is the process of objectively understanding the state or condition of a thing or entity by observation and measurement to determine its effectiveness.

Evaluation on the other hand is the process of observing and measuring an activity or thing with ultimate purpose of judging and determining the value of it. This could be by comparing it to something similar or to a defined standard. The end of an evaluation is an opinion.

The two synonyms *assessment* and *evaluation*, although both aim at gaining deep insights of a phenomenon or a thing, they don't necessarily mean the same thing in context.

Looking at the above definitions, it is subtly that assessment must happen in order to determine the value (i.e. evaluation) of an activity. One can for instance evaluate the (value of) effectiveness of methods used in assessing sustainability a farming approach.

Evaluation theories describe and prescribe what the evaluators do or should do when conducting an evaluation. Even though common vocabulary, definitions and shared conceptual and operational understanding has eluded many scholars and practitioners, theory-driven forms of evaluation have emerged as preferred methods in practice. Such approached have been widely adopted in one way or another and are common in the international arena for evaluations of impact of development programmes and projects (CORYN, NOAKES, WESTINE and SCHROETER 2011).

There are two typical models for theory-driven evaluations: Linear and non-linear program theory models.

In a linear model, elements used to describe or represent a program theory include (not always) inputs, activities and outputs (forming a program process theory) on one side to yield into initial, intermediate and long term outcomes, representing the program impact theory (DONALDSON, 2007). Inputs include various resources (e.g. labour, land, finances) necessary to implement a set of activities in the programme.

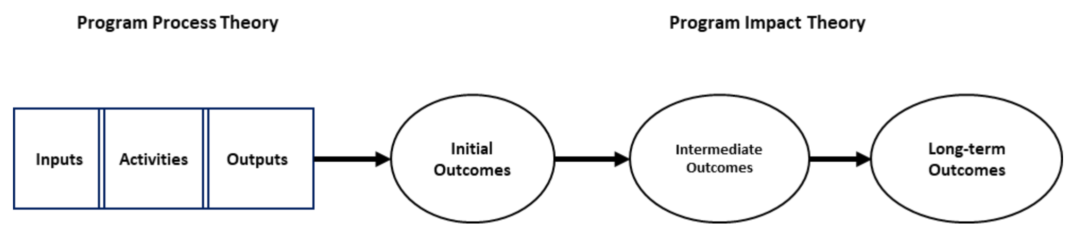

Figure 3-2: Linear program theory model (Source: DONALDSON 2007, in CORYN 2011).

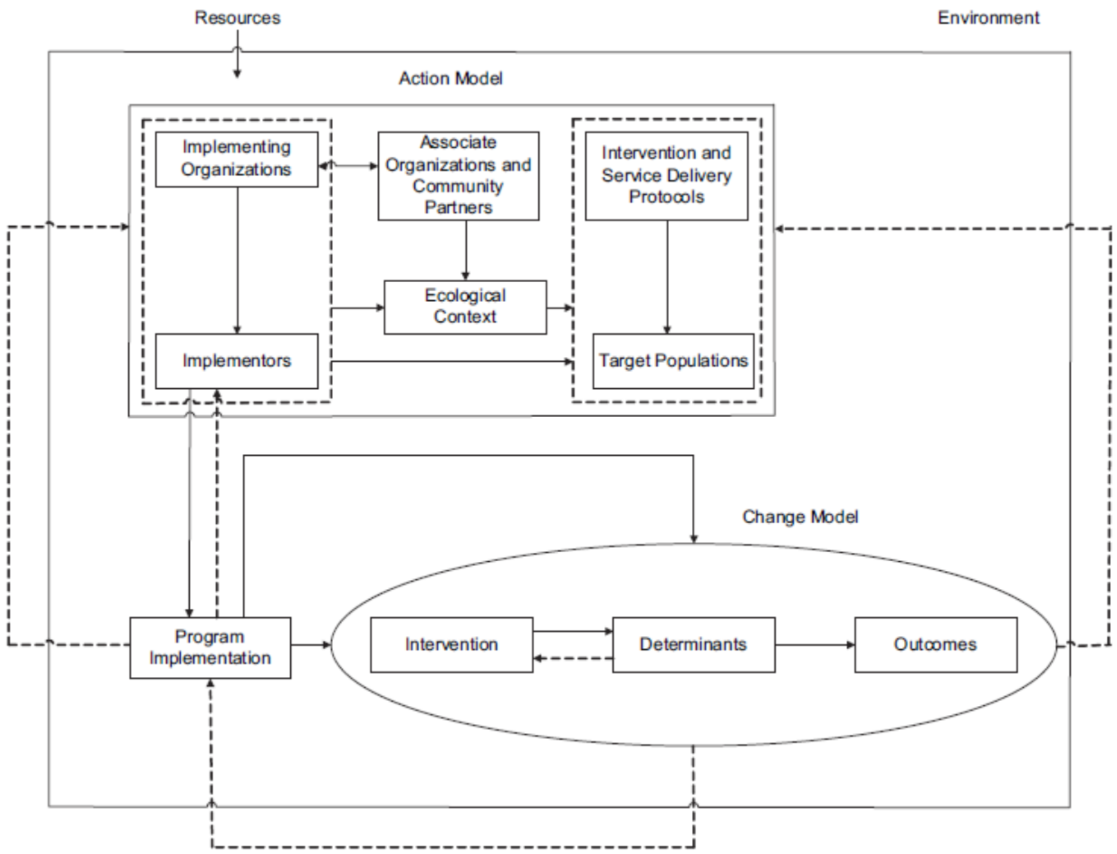

Figure 3-3: Non-linear program theory model: (CHEN 2005, IN CORYN 2011).

In these two models, activities are the actions that are taken to bring about the desired result or outputs. Outcomes are the expected changes or improvements (i.e. impacts) that occur as a direct or indirect consequence of the inputs, activities and outputs (CORYN et al. 2011).

However, programmes and projects are implemented in a real world with all its complexities. Linear models therefore may not be robust enough to evaluate the impacts of practical programme interventions. In such cases, a non-linear program theory model (Figure 3-3) is more appropriate.

3.4 Tools for assessing sustainability

Before proceeding to elaborate on the conceptual framework that was developed and adopted in this evaluation study, let's take a detour and look at some common tools that are used in assessing projects in terms of the impacts on sustainability. It is important to note that one of the characteristics of sustainability is that it is both universal and local context dependent (SEGHEZZO 2009). To design tools for evaluating sustainability is very difficult especially in the long term as it demands understanding current and future linkages and dependencies with the later (i.e. future) only as assumptions.

While sustainability requirements can be applied in a variety of ways, it is important that assessment criteria and processes need to be particularly well crafted and explicit for them to be applicable in this context to biofuels development programmes, polices and projects. There have been several ways to assess biofuels impacts in terms of its sustainability or against sustainable development tenets.

Below is a brief overview of methods and tools that can be (and have been) used to assess biofuels projects and their implications on sustainability evaluation.

3.4.1 Life Cycle Analysis

Life Cycle Analysis or Assessment (LCA) is the most commonly used approach by which environmental analysis is carried out during design process of a product or service. It assumes that appropriate scope for analysis is the entire life of the material, product or service (COATANEA 2006). LCA usually follows a four-step methodology that are: goal definition or scoping, inventory analysis, impact assessment and improvement assessment (SETAC, 1991). It is basically a cradle to grave way of looking at a product or service taking into consideration the resources that go into the production of those products or services.

The interest in LCA increased as a result of introduction of comprehensive legislature especially in the European countries. Corporate interests were also motivated to use

LCA when the EC Eco-Management and Audit Regulation was introduced in 1993 (CRAIGHILL and POWELL 1996). LCA has been criticised as being unreliable scientifically as a method because each stage, there is a significant scientific limitation. Such limitation includes the difficulties to identify the boundary of the system being analysed and lack of reliable inventory or baseline data on which to base the analysis (AYRES, 1995).

In the context of this study, LCA is not an appropriate method to evaluate the sustainability of Jatropha value chains since it (LCA) suits product assessment against environmental impacts mainly. In addition, because of the novelty of Jatropha value chains, there was no baseline data on which to base the assessment.

3.4.2 Climate change and agro-ecosystem resilience [SHARP]

Livelihood of over 70% of people in SSA is dependent on rain-fed agriculture and/or pastoralism and its related activities which makes them vulnerable when exposed to climate change and variability impacts. While various sets of indicators have been developed to assess resilience at large geographical scales and in urban environments, quantitative and qualitative indicators of resilience in agricultural ecosystems have often been poorly defined (CARPENTER 2001; BENNET 2005; CUMMING 2005; FLETCHER 2006; DARNHOFER 2010)

In this context, agro-ecosystems refer to ecosystems that have been altered by anthropogenic desires deliberately for provision of food and other products and so include socio-economic, environmental aspects with the infrastructure, markets, institutions and human actors (CABELL 2012; CHOPTIANY 2016].

The Self-evaluation and Holistic Assessment of Climate Change Resilience of farmers and Pastoralists (SHARP) is an assessment tool that was developed with the aim of filling the gap in current climate resilience assessment tools that worked at a local (i.e. community) scale while at the same time combining a scientifically rigorous foundation of resilience theory. It consists of a tablet-based survey with simple components that allow trained facilitators to support communities to assess the climate resilience priorities of farmers and pastoralists at individual household and community levels through discussion and survey responses to serve local communities and feed into national and regional discussions.

According to CHOPTIANY (2016) SHARP comprises:

- A tool built on comprehensive understanding of climate resilience that includes social, economic and environmental aspects at multiple scales (i.e. individual community and regional) for a range of smallholders.
- A participatory household-level assessment of climate resilience performed over school/cropping season that combines quantitative measurements of resilience indicators with participants' self-evaluation of the adequacy and importance of different farm/pastoral components to their overall livelihoods.
- An interactive learning and monitoring and assessment tool, using tablets that allow for immediate access to information resources, aiding with group discussions and identification of resilience priority actions
- A baseline assessment of climate resilience for better forecasting and countering climate change impacts in specific areas on community specific vulnerabilities and strengths.

In the absence of comprehensive tools to assess the vulnerability of communities and agro-ecosystems, SHARP was developed to improve among others the ability to measure meaningfully the resilience of agro-ecosystems in combination with other tools as it is designed to assess quantitative as well as qualitative information which can directly be taken into account to assess the perceived and expressed needs of farmers.

In the context of this study, resilience is not the only parameter to consider when evaluating sustainability of Jatropha production. However, from farming perspective, considering the complexity of the entire Jatropha value chain and the absence of implemented projects on the ground, SHARP model was found not to be suitable.

3.4.3 Participatory Impact Assessment Framework

In determining the social impacts of development interventions on the target group, it is important to involve the targeted beneficiaries in the evaluation in a participatory process. NGO sector when assessing impact of humanitarian assistance and development often integrate an approach known as Participatory Impact Assessment (or PIA).

PIA is an extension of a Participatory Rural Appraisal, a very well-known approach employed in development planning and assessment. The approach takes into consideration the local people (or project clients) as experts by stressing their involvement in assessing the project impacts and recognising their ability to identify and measure their own indicators of change (CATLEY 2007), or the lack of it.

PIA has eight aggregated stages that are: designing the indicatory questions to be answered; determine the location and time within the project boundary; identify the indicators and their priorities; choose and test methods to use in PIA; determine the sample size; Assess project attribution; Triangulate with other sources of data from similar interventions, provide feedback and verify findings with target group.

The advantage of using PIA is that it can measure the real impacts (i.e. outcomes, not outputs) of an intervention on the lives of the participating farmers in this case as opposed to focusing on whether the milestones in a project where attained (i.e. outputs, e.g. seeds and fertilizer delivered to centres).

In the context of this study, PIA was employed in a BIO-EX Project (See case in Chapter 5 of this thesis) to assess impact of the Jatropha experiment in North-western province in Zambia. Not all stages were followed in BIO-EX due to the sheer size of the project area, bad timing[13] and resource constraints and this may influence the result of socio impact assessment within the diversion-based evaluation framework.

[13] There was an agriculture show that was not communicated.

3.5 Conceptual framework for Diversion-Based Evaluation of Jatropha Biofuels Value Chains

The diversion-based framework for evaluation of Jatropha production and its value chains involves assessment of how each defined diversion would impact or influence (positively or negatively) the dimensions of sustainability. The sustainability dimensions that have been adopted for the purpose of developing a framework for evaluating sustainability is the 5DSM model by (SEGHEZZO 2009). At the end of the assessment, a subjective opinion of sustainability is done based on the assessment scores determined by observed and potential diversions in the case study areas. This then is triangulated with findings for similar interventions.

Resource diversion is not a novel concept. By 2008, the debate over the new competition between land for food and that for energy intensified. When the demand for both food and energy increases, the pressure on land conversion increases as well, that may lead to further climate change. This in turn may affect productivity and availability of land (HARVEY and PILGRIM 2011).

This trilemma[14] (food, energy, climate) challenge requires that the expansion of biofuels value chains must interact sustainably with other activities on land and eco-system services and therefore need some simple but robust enough framework that can be applied in determining the interaction. Looking at possible diversions presents an opportunity to develop a simple and yet interactive framework that can be used to evaluate biofuels value chains. In this study, Jatropha-based biofuels were evaluated against land, water, inputs, markets, investment and services diversions as they impacted people, location, environment, economy and resilience.

In this context, a diversion[15] is when the utilisation of a productive and/or institutional resource has potential to impact negatively on the biophysical environment; socio-economic environment and institutional environments that are important in sustaining the targeted beneficiaries. Only diversions for Jatropha development that

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[14] The term trilemma was coined BY TILMAN ET AL. (2009) to refer to “food, energy and environment”. I have used climate in this case as a constraint and/or driver in the context of food versus energy crop production as competing interests

[15] Collins Dictionary defines a diversion as an *action or event that attracts one’s attention away from what one is doing or concentrating on*, currently (my own emphasis)

had potential to harm food production, food security and loss of livelihoods at local level directly were considered. The diversion-based evaluation framework matrix is represented schematically in Figure 3-4.

	PEOPLE	CULTURAL	LOCATION	BIOPHYSICAL	PERMANENCE
DIVERSION / INDICATORS	What aspect and how is it impacted?	What part and how is it affected? e.g. food security	Where is the impact?	What and how is it impacted?	How permanent is the impact?
LAND (area and rights)	Access, ownership, income	Sovereignty, heritage, peace,	Farm, forest, homestead	Soil, land cover, eco-services, biodiversity	short term, medium term, long term
WATER (quantity, quality, access)	Access rights, ownership, health	Sovereignty, heritage, peace,	Farm, grazing, homestead, river, borehole	Quantity, quality, access to, soil,	short term, medium term, long term
INPUTS (Labour, fertilizer, seed, technology, finance)	Income, productivity	Society problems, food security, heritage	Farm, homestead		short term, medium term, long term
MARKETS (local, national, international)	Income, revenue tax, opportunity	Trust, dependency, heritage,	Farm, homestead,	Land, forest	short term, medium term, long term
INSTITUTIONAL SERVICES (legal, extension, loans, training, communication)	Rights, training, knowledge,	Dependency, information, heritage	Farm, settlement, homestead	Land, forest, land cover,	short term, medium term, long term

Figure 3-4: Diversion-based evaluation framework: (Author’s own)

3.6 Application of the proposed framework

The described tools and methods of assessing sustainability have demonstrated that it is important to clarify what the sustainability context is in order to provide the basic criteria and indicators for evaluations and decision making. Clarification of the essential core context, in this case biofuels, would supply basic guidance for future applications. Neither core criteria nor basic process guidance can possibly be adequate. Both need to be built upon in diverse ways for various contexts and circumstances (GIBSON, 2005).

This is the departure point in the application of the proposed framework. The framework is applied in a three phased approach namely; context setting and delimitation of the project area; identifying and defining the key diversions that may be applicable with the target community; collecting and collating secondary data; field work (interviews and physical observations) to obtain primary data, and then performing meta-analysis to evaluation the project for sustainability. The obtained data is then triangulated with existing data from official sources like the National Statistics Offices to validate the obtained information.

Using a simple aggregation to calculate the score for each score. In the example in, using the indicators, a score of 4 was obtained for BIO-EX (Zambia), BERL (Malawi), Shankara Jatropha Out-growers (SJO, Namibia) and Kapiri Jatropha Farmers (Zambia). These implement a similar farming model and hence the potential risk for diversion of labour to manage the plantations is high. This may in turn affect food security. Figure 3-5 shows the resulting sustainability score.

Table 3-1: Input diversion aggregated score for case projects: (Author's own)

	Labour	Fertilizer	Finance	I-score
BIO-EX	4	3	2	9
D1-BP	5	0	5	10
KAPIRI	4	4	3	11
KJGA	5	0	5	10
SJO	4	4	3	11
LLD	5	0	3	8
BERL	4	3	2	9

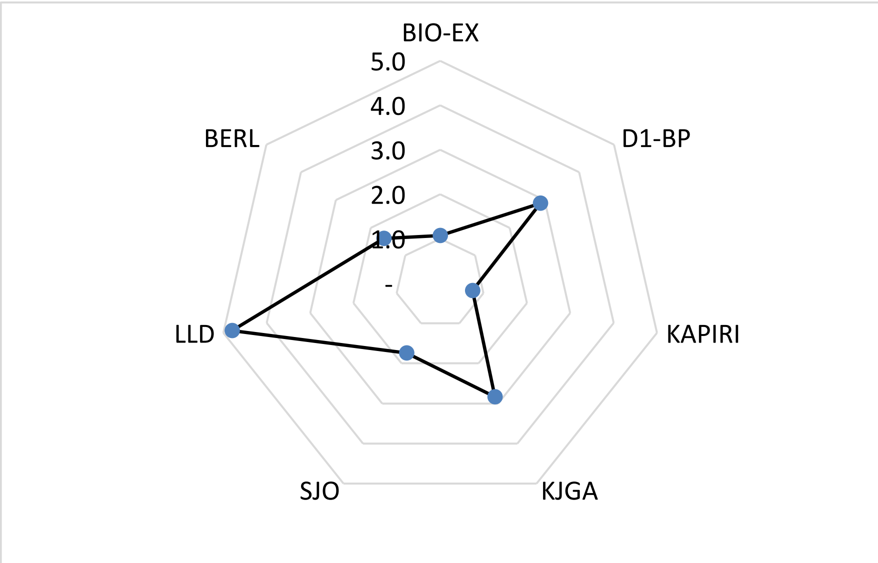

Figure 3-5: Sustainability and food security risk potential: (Author's Own)

4 Jatropha Curcas L (JCL) as a plant and its potential as an energy crop

The choice of biofuel feedstock option is dictated by a number of factors. Before discussing the comparativeness and competitiveness (if any) of Jatropha with other crops, it is important to highlight a few characteristics of this plant and this chapter focuses therefore on *Jatropha Curcas L* (referred to as Jatropha) as plant. It describes the plant both physiologically and in terms of its ability and biophysical demands as an energy crop. Its properties to contribute to curbing GHG emission is also analysed and the chapter ends with an evaluation of Jatropha as an energy crop alternative in the SADC region.

4.1 Physical characteristics as a plant

There are about 170 species of this plant so far described in literature, but the *name Jatropha Curcas L* has come to mean mainly Jatropha recently (JONGSCHAAP 2007), and is therefore, adopted in this work as well.

Figure 4-1: Jatropha *Curcas L:* (Author's own: top left, Dec 2009, top right May 2010, bottom left Nov 2008, bottom right June 2015)

4.1.1 Origin and occurrence

The plant *Jatropha Curcas L* (Linnaeus) belongs to the family of spurges (i.e. Euphorbiaceae) and is commonly known as *physic nut*. It is believed to be indigenous to Latin America but has naturalised throughout the tropical and subtropical regions of Asia and Africa (AUGUSTUS 2002). The first record of it being transplanted and moved out of its natural environment is dated as far back as the 16 Century. This is evidenced by the fact that Jatropha has local names in many places where it has naturalised.

It is called "Mbono Kiburi" in Swahili, translated literally as a "grave yard tree" owing to its traditional use as grave yard tree planted to indicate location and ornament as it could be planted in any season in Tanzania. The Haya people of Lake Victoria call it "Mwintankoba" meaning a "thunder tree" as it was traditionally planted near a house to prevent homes from being destroyed by lightning (Steylus L et al date?). Among the Bemba people in Zambia it is called "Umutondo Mono" owing to its seeds resemblance in appearance and character to castor oil seeds which are called "Imono". It was used to produce oil for babies to protect them against insect bites and other skin diseases (MKOMA AND MABIKI 2011).

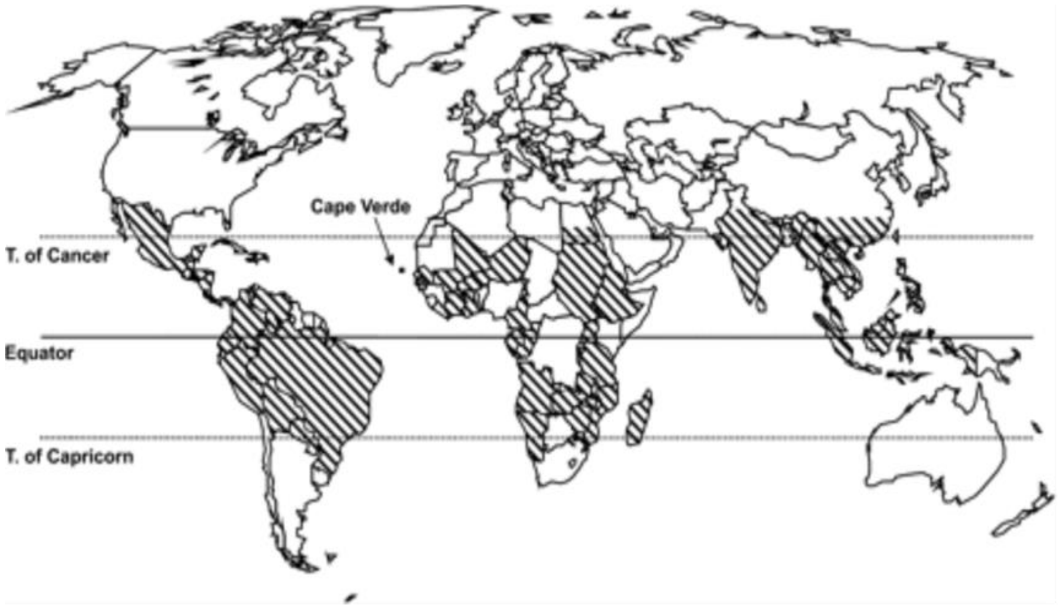

Figure 4-2: Shaded Regions showing global distribution of Jatropha: (KING 2009)[16]

[16] Weakness: Jatropha is in e.g. DR Congo, Nigeria, and Kenya but map authors missed this, an example of a poor map

From this map, Jatropha is found in many parts of the SADC countries and it has been reported as a non-invasive alien tree (Palmer 1972). Recent reviews have corroborated that it does not constitute a major threat to the environment, but it is not grown commercially in South Africa, Botswana and Namibia[17].

4.1.2 Phenology and growth patterns

Jatropha is a succulent bushy perennial shrub that generally grows to a height of 6 depending on the biophysical conditions (Augustus 2002). It grows in tropical and subtropical regions within a cultivation limit at 30°N and 35°S (Heller 1996). The plant is well adapted to harsh conditions in arid and semi-arid climates where it sheds its leaves at the beginning of the dry season (ORWA 2009). Rainfall induces flowering and with adequate water, good pollinators and overall favourable conditions, Jatropha can thrive to flower and produce fruits throughout the entire year (Kumar 2008).

Although Jatropha as a plant has spread widely across the world, very little data on its growth and productivity were available at the start of this study. A detailed study of the plant in trial and commercial plots was therefore necessary to establish and assess the relationship between agro-climatic conditions, agronomy and growth on one hand and productivity on the other.

Figure 4-3: Root structure of a Jatropha mature tree: (Photo Prime Investment, January 2009, Divundu)

[17] Attempts were made in Namibia to commercially grow Jatropha, but all efforts came to nothing when government decided to ban it. South Africa considers Jatropha to be among dangerous plants with potential to become an alien invasive plant and therefore no commercial planting is permitted

4.2 Biophysical demands of Jatropha productivity

Although Jatropha is well adapted in Southern Africa, it needs certain agro-ecological conditions to produce enough biomass and fruits from which seeds can be collected. This section describes the ago-climatic and agronomic requirements for a viable seed yield for Jatropha.

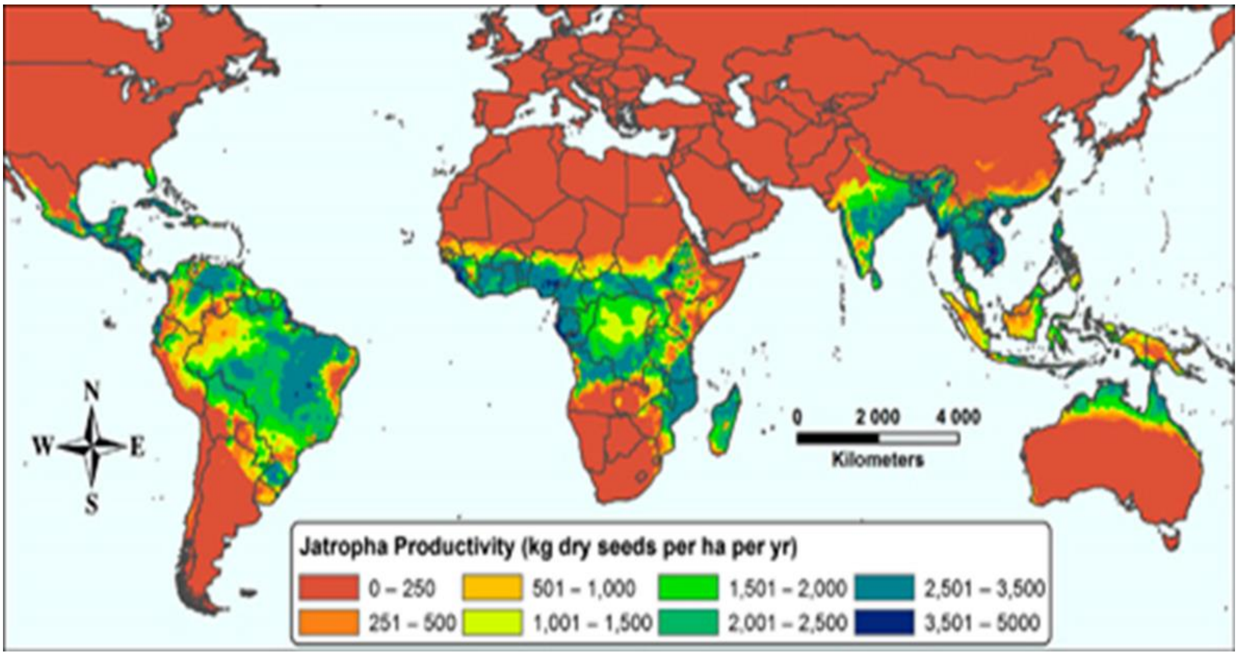

Figure 4-4: Estimated Jatropha productivity (kg dry seeds ha-1 yr-1) for present climatic conditions (1950-2000 average): (TRABUCCO 2010)

4.2.1 Agro-climatic conditions

The quality and quantity of biodiesel produced from plant oil depends on the amount and quality of vegetable oil used. Climate plays an important role in determining this factor. The absence of reliable field assessments of agro-climatic and physiological knowledge and data on Jatropha meant that the implementation of large-scale projects was a risky undertaking. To fill the gap, a novel two step approach of integrating knowledge from biogeography and population biology with available Jatropha field data was done to model Jatropha productivity potential against bioclimatic conditions. Then Jatropha seed yield in response to climate was mapped worldwide for actual (1950-2000 average) and future (2020) climate conditions. The result of this indicated that climate variables most significant to yield response were annual average temperature, minimum temperature, annual precipitation and precipitation seasonality (Trabucco, et al., 2010).

Table 4-1: Average estimated Jatropha productivity within Koppen Climate Zones: (adapted from TRABUCCO 2010)

Koppen Climate Zone		Average productivity (kg dry seeds per ha per year
Tropical humid climates	**Af** (wet-no dry season)	1150
	Am (monsoonal -short dry season, heavy monsoonal rains in other months)	2200
	Aw (savanna -winter dry season)	2300
Dry Climates	**BSh** (subtropical steppe – low latitude)	750
Subtropical temperate climates	**Cw** (humid subtropical – dry winter)	1950
	Cf (humid subtropical/marine without dry season -hot or warm summers)	1550

Figure 4-4 indicates that Southern African countries (e.g. Zambia, Malawi and Mozambique and Namibia to some extent) are suitable for Jatropha cultivation agro-ecologically. However, it does not include the potential of agronomic practices to mitigate climate stresses that can widen the area suitable for Jatropha (TRABUCCO 2010).

At the time of this study, these results were used to compare with the yields from trials plots to determine the nature of agro-climatic conditions required for Jatropha production.

Table 4-2: Jatropha Agro-climatic conditions[18] compared to study countries climate[19]

Agro-climatic Conditions	Jatropha Requirement	Malawi	Namibia – Caprivi Strip	Zambia Copperbelt
Mean Annual Temp °C	18-28	24	30	28
Mean Annual Rainfall mm	600-1500	760 – 1143	550- 800	700 - 1600

4.2.2 Soil conditions

The best soils for Jatropha are aerated sands and loam soils of at least 45 cm deep, according to FAO 2009, (citing GOUR 2006). Heavy clay soils are less suitable because drainage is impaired. Ability to grow in alkaline soils has been widely reported but soil pH should be between 6.0 to 8.0/8.5. Although Jatropha has been found to survive in very poor dry soils in conditions considered marginal for agriculture, its ability to survive does not translate into high productivity under such conditions. Jatropha has adapted to tolerate poor soils but for a viable Jatropha crop for biodiesel production, fertile soils with adequate rainfall are prerequisites for acceptable seed yields.

4.2.3 Nursery and field trials

Six nurseries were established with seeds that were obtained from different areas in each country and across countries. For example, seeds from Namibia were also planted in Zambia to see how they performed and vice versa. Seed selection was crucial and criteria for seed selection was developed based on size and weight, oil content and agro-climatic conditions. This was done as a means of determining whether there was any correlation between these factors and performance of Jatropha. The seeds were obtained from Jatropha trees of varying years.

[18] Jatropha productivity estimates against climate by TRABUCCO 2010
[19] https://en.climate-data.org/africa/zambia/copperbelt-province/kitwe-5830/#climate-graph

Seeds were subjected to different treatment for example drying method (direct sun or shaded drying) and were also sent to two agriculture research centres to determine germination rates.

Mount Mukulu Research Station in Zambia planted seeds obtained from the National Scientific and Industrial Research Centre (NSIRC), Kitwe Zambia and seeds that were harvested from trees that were found in Divundu in the Caprivi Strip of Namibia.

Six (in total) nurseries were established in Namibia and Zambia to study the plant from seed to tree under different conditions.

Nurseries preparation involved getting different soil mixtures. Some seeds were sown in pure sterilised sand; some in sand enriched by wood saw dust and then some in loamy soils in 12mm x 200mm poly bags. 200 poly bags with one nursery mixture and seed type and source was sown at 20mm deep in moist soil and no watering was done on the first day. After that water sprinkling at 3-4 days intervals in sun protected nurseries were done while every day for those under the sun.

In addition to the poly bag nurseries, bed nurseries in commercial plots were established and observed in the similar way except in Namibia where they had to be treated with more water and water retention polymers which were inserted before planting.

Table 4-3: Nursery location, source of seed and germination rates obtained: (Author's own).

Nursery	Place and Country	Source	G-rate
Forestry Office	Rundu, Namibia	Divundu	84%
Herom Trent	Grootfontein, Namibia	Divundu	65%
Shankara	Caprivi, Namibia	Divundu	87%
Omatako	Otjozondjupa, Namibia	Divundu	62%
Parklands	Kitwe, Zambia	NSIR Centre, Choma	92%
Mount Makulu	Chilanga, Zambia	Divundu, NSIRCN	96%

Jatropha grows primarily from epical meristems and have a sympodial branching structure. It was observed that after year two, the branches bend over from its own weight and the plant produces side shoots from the top side of the branches at the location of the previous year's leaf buds. These shoots grow rapidly and reach a diameter of 1 cm to 2 cm and attain a height of average 1.3 m within the first three months of a new growing season. However rapid increase in weight often led to breaking of branches and therefore it needed to be managed in the early stages to avoid loss of biomass.

4.2.4 Jatropha seed production and yields per hectare (YPH)

At the peak of the Jatropha hype, the range in terms of yield per hectare (YPH) found in literature ranged between 0.6 metric tons to 27 metric tons. Many projects initially led by government and NGOs in developing countries relied on these yields and claims to promote Jatropha as a strategic bioenergy feedstock. Higher and stable yields are essential conditions for economic feasibility of any plantation (IIYAMA 2013).

However, there was lack of evidence of such claims at the time of this research and therefore it became clear and important to conduct empirical studied in situ for both planted and found "wild" trees. A method developed in one commercial project to determine the relationship between the age of trees and amount of fruits, hence seeds, produced per tree was adopted, modified and applied in this study. These results were then used to calculate potential YPH of different field planting densities in different agro-climatic conditions in Namibia and Zambia.

Mature trees were identified in different agro-ecological zones in Namibia and Zambia. The ages of these trees were determined using the adopted modified method and efforts were made to collect all the seeds each tree using local labour. These trees were geocoded, fenced off and a plastic was laid under each tree to collect every seed that fell from such a tree for two seasons. These seeds per tree were then subjected to mass determination and then YPH estimated with certain assumption that all the trees in the field had same or similar health. Table 4-4 shows the results of seed production estimation for observed trees and their potential yields in fields of varying plant densities.

4.2.5 Pests and disease

Jatropha was hailed as a tough tree that is not susceptible to pests and diseases. Field observations revealed that both wild trees and those in established plantation suffered from pests and diseases. The common pests that were found included golden flea (blue) beetle, leaf miner, termites and rodents. Some trees at the Katima Mulilo trial plantation were attacked by a fungal infection. It was observed by the author that trees that were thriving in the wild or planted as ornamental trees with considerable spacing between trees showed no or little signs of pest or disease prevalence. Jatropha trees in trial plantations both in Namibia (Katima Mulilo) and Zambia (e.g. Kachumu) had pests and signs of disease attacks. In the absence of knowledge on how to treat these, it is recommended that integrated and disease management measures must accompany Jatropha cultivation, contrary to what earlier literature suggested.

Figure 4-5: Common pests and disease on Jatropha: (Author's Own May 2009, Katima)

4.2.6 Jatropha oil suitability as a feedstock for biodiesel production

Several factors determine the suitability of a feedstock to produce biodiesel. At the time of the study, the target countries in southern Africa had not defined their local standards for biodiesel nor did they set targets for blending. However, since the produced biodiesel was primarily targeted to meet the EU targets, suitability of a feedstock, therefore, was dictated by the EU market as described in the EN14214 Standard.

The ability of biodiesel to meet a specified criterion for a standard is largely determined by the fatty acid composition. Cetane number (or CN), cold-flow and cloud point properties, kinetic viscosity and oxidative stability are all influenced by the fatty acid composition. The use of vegetable oil directly has been deemed unsatisfactory due to the high viscosity, Free Fatty Acid (FFA) content and the matter of carbon deposits (NIGAM 2011). The production of first-generation biodiesel involves trans-esterification of the vegetable oil with methanol in the presence of catalyst to produce fatty acid methyl esters, scientifically referred to as FAMES and reduces viscosity of the oil (KING 2009).

Properties of oil extracted from Jatropha has saturated fatty acid content typically of 14-16 % palmitate and 5-8 % stearate (FOIDL 1996). The cloud point of 4-8 ^{o}C has been deemed to be too high for use in temperate climates in winter as 100 % (B100) biodiesel but suitable in blends of up to 10%. In terms of kinetic viscosity for the EN14214 of 3.5-5.0 mm^2 per second at 40 ^{o}C, FAMES from Jatropha falls within these values and therefore suitable (KRISHNAKUMAR, VENKATACHALAPATHY and ELANCHELIYAN, 2008).

4.2.7 Carbon Sequestration Potential

The Emission Gap Report (UNEP 2017) stated that the reduction potential in 2030 ($GtCO_2e$ per year) for bio-energy in the energy sector and by biofuels for the transport sector was 0.85 and between 0.63-0.81 respectively. This translates to 15 % of total reduction potential sectoral aggregate for the transport sector. This means that biofuels are an important green development option for the reducing the emission gap for the 2^{o}C threshold by 2030.

One of the important aspects of biofuels is its impact on the carbon cycle during growth and utilisation. The Roundtable on Sustainable Biometrics (RSB) estimated that the amount of CO_2 emitted by one average car driving around 18 300 km per year would be 4.7 tCO_2 per year (RSB 2016). Biofuels promise to compensate against this since the plants use CO_2 in their growth and so the amount used in transportation corrected. Understanding the potential of biofuel feedstock to reduce amount of CO_2 emissions is as important as the amount of energy produced (RSB

Since there were no reliable data in literature about the actual potential of Jatropha in terms of carbon sequestration, it was necessary to carry out empirical studies to establish this potential. The method adopted involved determining the biomass of the woody part of the selected trees above the surface and that of the woody part below the surface. Leaves and seeds were discounted as they did not have significant bearing on the amount of carbon stored per tree. Since age of the tree influences biomass of perennial trees, it was important to obtain biomass of trees per age. This is particularly important to determine the optimum age of tree at which seed, and biomass has highest value in order to contribute positively to Yield per Hectare (YPH) and negatively to Carbon per Hectare (CPH).

Using the dried mass, the carbon content was estimated, and this was used to determine the CO_2 sequestration potential per tree and extrapolated per ha at 1600 planting densities. When the data was analysed, and it was clear that there was a strong correlation between age and amount of biomass.

Table 4-4 shows that older trees with increased biomass had potential to capture more CO_2 than young ones. The amount of CO_2 captured per hectare can be increased by increasing the tree density per hectare. However, this need to be weighed against the loss of seed yield and subsequent seed oil per hectare.

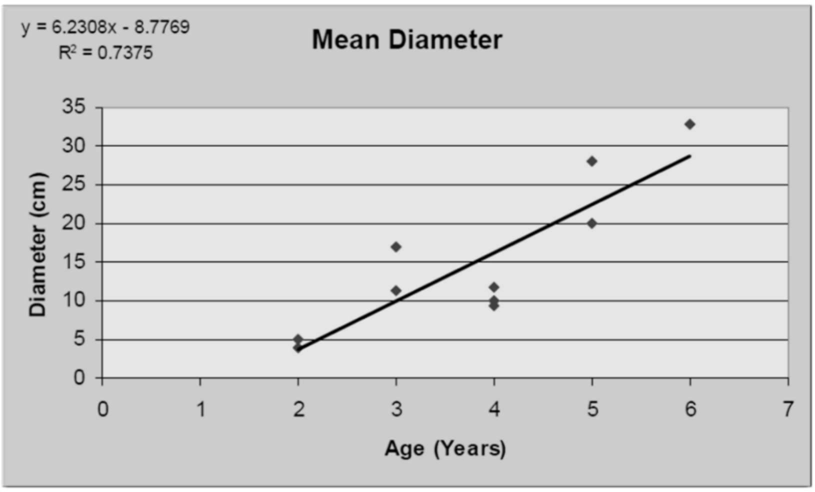

Figure 4-6: Relationship between age and stem of Jatropha trees: (Author's own)

With higher planting densities in better agro-ecological zones in in Zambia's Copperbelt and Luapula Provinces due to high rainfall area, the amount to be captured is potentially higher than in Namibia. The net CO_2 balance maybe be higher in Namibia if planted on wasteland conditions.

Table 4-4: Jatropha CO2 sequestration potential: (Author's own)

Age	**Dry mass/tree (kg)**	**Carbon/tree kg**	**CO_2 per tree in kg**	**CO_2 per Ha Metric tons**
2	1.54	0.63	2.31	3.69
3	5.23	2.15	7.86	12.58
4	6.68	2.74	10.03	16
5	26.59	10.90	39.94	63.90
6	48.30	19.80	72.54	116.07

However, this assessment was not based on the life cycle of biodiesel from Jatropha seed oil but simple calculation of carbon stock in the plant itself. The Jatropha biodiesel CO_2 reduction rate was assessed by ACHTEN 2010 based on minimum, medium and high Jatropha above ground biomass (including seed) needed to repay carbon debt and estimated that 20-year-old plantation stores 48-74 tCO_2-eq per hectare.

4.3 Robustness of Jatropha as an energy crop

Exploratory field work conducted in the region indicates that Jatropha as a plant has adapted to Southern African regional climate. This is because there were significant number of healthy trees that were prevalent and scattered in all study countries, Tanzania and Zimbabwe. The varieties that were found in the countries that were visited included some varieties that could give four seeds per fruits. This means that if such a variety was adopted as a cultivar, it could increase the biomass and oil yields per hectare.

The claims that Jatropha can tolerate drought condition was proven by the trial plot of four hectares planted at Divundu (Shadikongoro). The photo on the left in Figure

4-1 shows the plant during a drought period and the one on the right shows the same trees after two months of good rainfall.

Figure 4-7: Same Jatropha trees at different rain conditions: (Author's own, left photo September and right photo December 2010)

In terms of the robustness of Jatropha as an energy crop, the empirical trials that were conducted in Namibia and Zambia indicated that the seed production and total yields are well below the seven tons and higher as found in the literature at the time of study (PANT 2006; HELLER 1996). Namibia sampled trees in the Okavango indicated a yield of 1.7 tons average for trees over five years old with yields increasing to 2.1 tons for older trees. In trial plots in Namibia where strict agronomy practice such as fertilization, pruning and irrigation was done, yields increased to 3 tons per hectare. The Zambian trials recorded a bountiful potential of average 5.2 tons per hectare in Msoro area of Eastern Province while Lufwanyama area and Luapula recorded the highest yield potential of 6.6 and 6.32 tons respectively.

Table 4-5 shows the average seed production per tree and yield per hectare for the sampled five-year-old found Jatropha trees and those in trial plots with optimal conditions.

Table 4-5: Comparison of Jatropha mean seed yield per ha (YPH): (Author's own)

	Wild Trees assume 1600 trees ha^{-1}			Trees in trial plots of 1600 trees ha^{-1}	
Site	**Seed mass $tree^{-1}$ (g)**	**YPH (MT)**	**Site**	**Seed mass $tree^{-1}$ (g)**	**YPH (MT)**
Shighuru	1078	1.7	Divundu	1875	3.0
Lufwanyama	1386	2.2	Kitwe	4125	6.6
Msoro	1267	2.0	Msoro	3250	5.2
Luapula	1392	2.2	Mansa	3875	6.3

The results indicate that wild Jatropha cannot provide the yields per hectare for a thriving biofuel sector even when high prices for crude petroleum are prevalent. Just like any other plant, Jatropha need to be domesticated and grown like any other crop to attain anticipated yields per hectare that makes sense for crude oil production to enter the biofuels value chain. Therefore, further research is needed to fully domestic this plant by developing new varieties that can produce high amount of seeds and oil with minimum input. This should be a pre-condition before major pronouncements of huge investment in the production of Jatropha as an energy crop.

It was difficult to determine which specific factors that increased the yields significantly in Namibia as the plants were treated the same by the forestry officers in Rundu and the farmers due to limited knowledge of why the experiments were designed in such a way. In the remaining sites in Zambia and the Caprivi, irrigation, pruning and fertilization plus ash application increased agility and yields. There were no field trials in Malawi and Mozambique but the climatic conditions in these countries and availability of good soils may have yielded similar or better results to those in Zambia.

4.4 Concluding remarks on potential of Jatropha

At the peak of global bioenergy development, driven by the need to meet the targets pronounced especially by the EU, Jatropha was widely promoted by the private sector and NGOs. The reason behind this was the belief Jatropha could grow easily on land that would not be suitable for food production and that it could thrive under different extreme weather conditions such prolonged droughts. The food security and land scarcity concerns raised attention of Jatropha as a sustainable biofuel source for marginal and degraded semi-arid areas (FAIRLESS 2007; NGONG 2009). This belief in Jatropha coupled with the projected increase in global demand for biofuel triggered massive promotion and implementation of Jatropha plantations by both private and public sectors (PLANNING COMMISSION OF INDIA 2003).

Scarcity of data on Jatropha genetics and its basic agronomy and biophysical demands, as also observed by (ACHTEN 2010) motivated this author to carry out empirical studies to determine whether the claims in existing literature were valid on Jatropha's potential. The experiments done on Jatropha as a plant in different agro-ecological conditions by the author indicated that, like any other crop, Jatropha need good agro-ecological conditions and optimal agronomic husbandry to thrive as an energy crop. The data showed that "wild" Jatropha in semi-arid regions of southern Africa had low yields compared, regardless of age, to those in more sub-tropical to tropical conditions which presented good loamy sandy soils and rainfall. Jatropha plants that were tried in Omatako Mountains and Heron Trent in Otjozondjupa Region in Namibia had the worst results. This is because the areas are prone to prolonged frost in winter. This confirms literature claims that frost conditions has a very bad effect on plant growth and flowering and therefore not recommended to grow Jatropha in frost prone areas like this. Luapula and Lufwanyama trials in Zambia showed the highest yield potential of above six tons, which could yield vegetable oil of about two thousand litres with proper extraction methods. These areas exhibit good well drained loam soils, more than enough rainfall and temperature that favour Jatropha and other crops.

In terms of carbon dioxide capture potential, the experiments showed that a mature tree has potential to sequestrate over 70 kg of CO_2 translating to nearly 200 metric tons of CO_2 per hectare. With oil properties falling within the required fatty acid range, Jatropha could potentially be considered as a viable oil-bearing plant for biodiesel production, assuming all enablers are in place such access to investment, labour, land, water and markets.

The story of Jatropha-based biofuels has been described as one of the "riches to rags" since large scale Jatropha projects across Southern Africa failed miserably. This motivated the author to conduct meta evaluations of case studies that were selected to understand why most (if not all) projects failed to deliver on the promises of Jatropha and assess the impacts such projects had on food production, food security and sustainability. The next chapter will discuss the results of the case studies in three SADC different countries.

5 Case Studies Description and comparisons

To determine the effectives of the Diversion-based Evaluation Framework developed in chapter three, Jatropha biofuels projects implemented in the SADC region were used as case studies. This chapter describes and discusses the results per country of interest. It first gives an overview of each country before describing and discussing briefly the specific project that was evaluated. The computed results using the DBEF are then displayed and discussed in relation to food security and sustainability.

5.1 Malawi; Overview

Malawi, (a former British Protectorate independent in 1964), is a landlocked country in the south-eastern Africa stretching between 9^{o} 30 S and 17^{o} S at its southern tip. It is bordered by three neighbours; Zambia to the west, Tanzania in the north and east and engulfed by Mozambique in the south and southwest. It was part of the Federation of Rhodesia and Nyasaland and as a result exhibits some of Great Britain's colonial legacies, common in the former Northern Rhodesia (now Zambia) and Southern Rhodesia (now Zimbabwe).

It is part of the East African (or Great) Rift Valley with incredible highlands, rivers and lakes. 20% of its total area is covered by Lake Malawi. With a landmass of 118 484 square km and a population estimated at 18.6 million people with an annual growth rate averaging 2.9% since 2010 (UNFPA, 2017), Malawi is one of the most densely populated countries in Africa with a population density of 140 persons/sq.km.

Malawi's climate is subtropical and varies widely with its terrain; semi-arid in the lower Shire Valley, semi-arid to Sub-humid on the plateaux and Sub-humid in the highlands. Near Lake Malawi, the mean annual temperature is 24^{o} C. In general, Malawi's seasons can be divided into cool (May to August), hot period (September to November) and the rainy season extending from November to April. Most of the country receives between 763 mm to 1143 mm mean rainfall per annum with over 1500 mm in Mulanje, Nkhata Bay and the northern end of Lake Malawi. The main rain bearing system in Malawi is the Inter-Tropical Convergence Zone (ITCZ), which is responsible for most the rain received in the country.

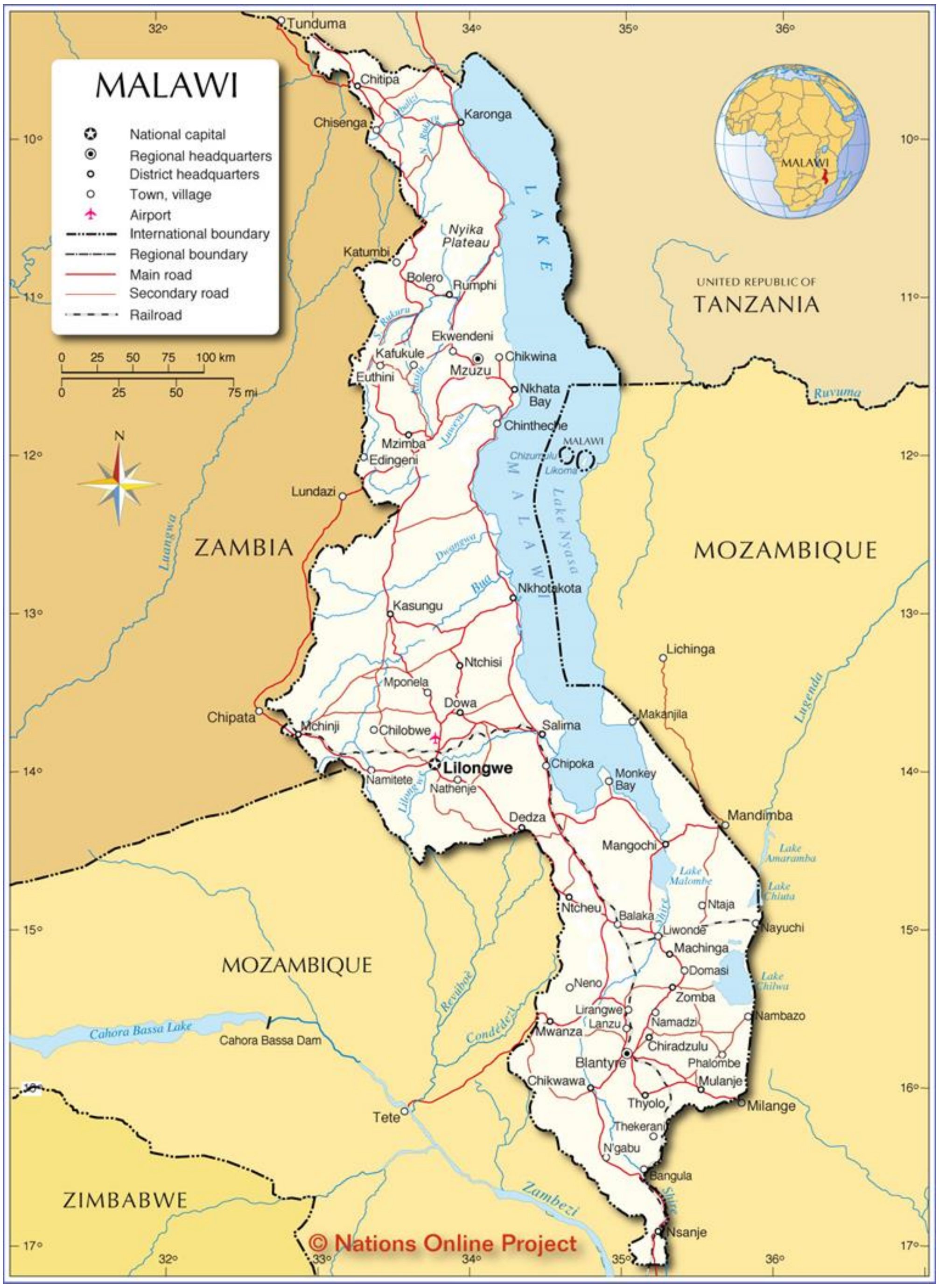

Figure 5-1: Location map of Malawi: (Source: Nationsonline)

5.1.1 Agro-ecological zones and potential in Malawi

Important to Malawi's agriculture sector is the massive depression running from north to south and containing Lake Malawi and the Shire River valley in the south.

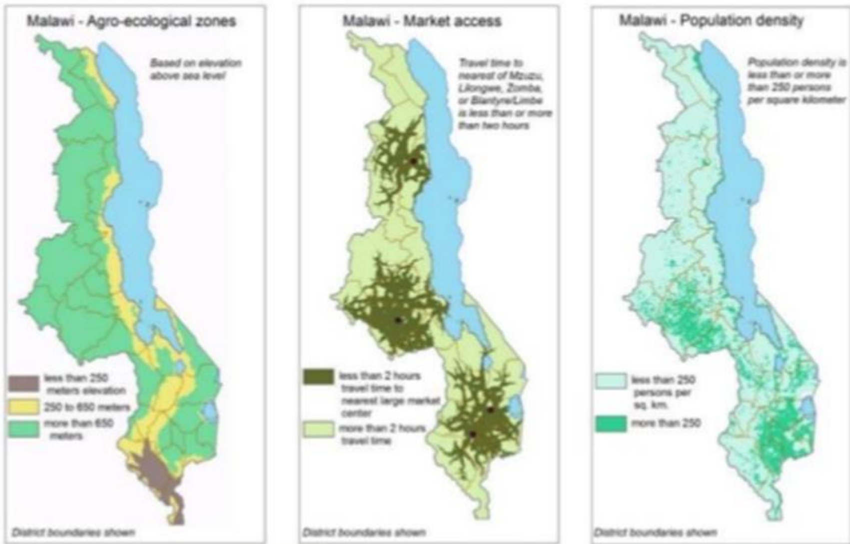

Figure 5-2: Agro-ecological zones in Malawi: (Courtesy, Malaw Government, 2011)

5.1.2 Agriculture, economy and Climate Change Implications

Malawi's GDP lingers around USD 3.3 billion with GPD per capital of USD 252. Despite having shown impressive growth, Malawi's foreign debt stock has risen in the last five years to levels of 2008. The agricultural sector is composed of smallholder farmers and estate farmers. Of the 9.4 million hectares of land available for agriculture, 32% are suitable for rain-fed agriculture on which some 3.1 million farm families share 6.5 million hectares contributing 80% of its total agricultural output. These small subsistence farmers have access to a mere 0.6 ha of land with customary land rights only. The estate subsectors share 1.2 million ha (13% of Malawi's total land available for agriculture) under leaseholds or freehold tenure systems. These estate farmers cultivate mainly cash crops such as tobacco, tea and sugarcane.

The main crops are maize (which is the stable food), cassava, rice, pulses, soybeans, tobacco, sugarcane, tea, cotton, coffee, cashew, macadamia, sweet and Irish potatoes. Wheat, sunflower, sesame, paprika and chillies and rubber are also grown but at a very small scale with rubber becoming important cash crop also.

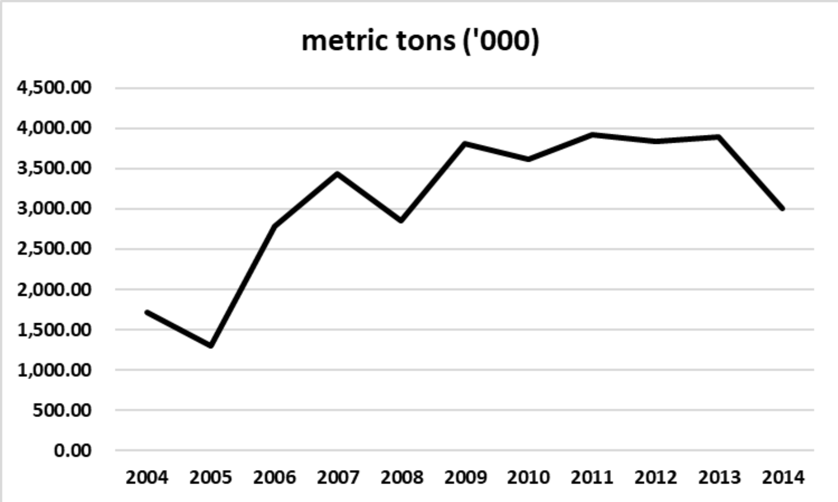

Figure 5-3: Cereal production trend in Malawi: (Author’s own, data FAO 2017)

Agriculture is the mainstay of the Malawian economy contributing 40% to the GNP and over 90% of its export earnings. Malawi main export is tobacco accounting for 60% of total export earnings followed by tea and sugar, while rubber and coffee are becoming important cash crops in the economy (SADC RAP 2011).

Food demand in Malawi has been increasing steadily and this is attributed to the increase in population and the effect of frequent droughts that cause low yields and widespread crop failures. Coupled with the increase in terms of land shortage and smallness of family holding, it is increasingly becoming difficult for Malawi to meet its food requirements especially cereals (FAO 2006).

Malawi has abundant surface water resources but this potential for irrigation is severely underutilized with only 78 000 ha (20%) of total 400 000 ha potential for irrigated crop production. The apparent land shortages, smallness of family holdings, consistency of droughts and crop failures is a threat to sustainability of agriculture production in Malawi. As a result, Malawi's agricultural production systems are highly sensitive to new crops and expansion of production.

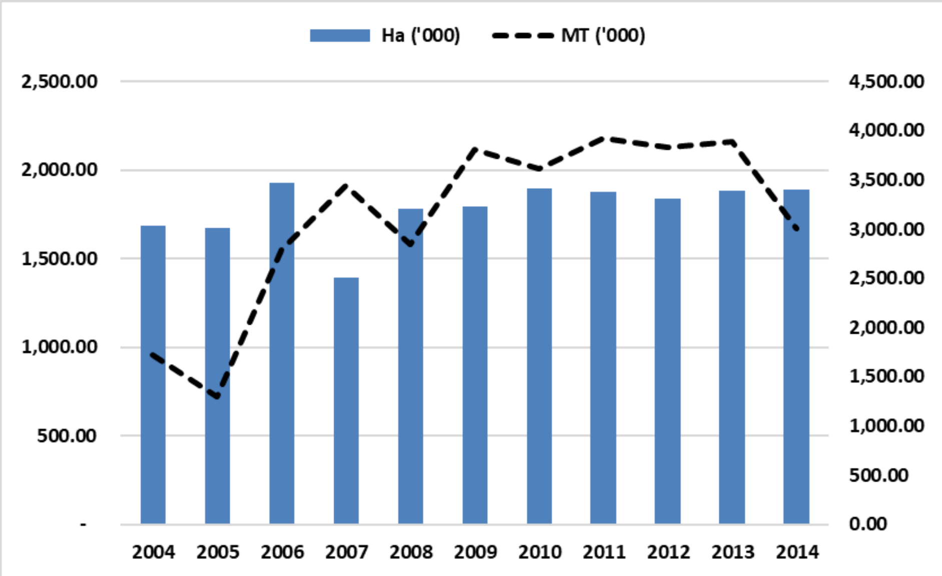

Figure 5-4: Cereal output compared to area planted: (Author's own, data FAO 2017)

5.1.3 Legal and Institutional Framework in the Energy Sector

Malawi relies heavily on three primary energy supplies namely hydropower, biomass and fossil fuels (imported petroleum and local coal). The contribution and penetration of solar and wind energy is basically non-existent at national scale. All the petroleum and its related products are imported by using 10% of its foreign currency earnings.

Biomass remains the primary source of energy accounting for nearly 90% of its national supply. Only 2% of its rural population has access to electricity (NSO 2009).

The energy sector in Malawi is governed by an Energy Legal Framework that includes three legal instruments namely the Energy Regulation Act; the Electricity Act, the Rural Electrification Act; the Liquid Fuels and Gas Act; the Coal Act. All these were proposed by the Energy Policy of 2003 that recommended combination of the National Electricity Council (NECO) and the Petroleum Control Commission (PCC) that was responsible for regulation electricity and liquid fuels Sub-sectors respectively into Malawi Energy Regulation Authority (MERA). Therefore, MERA established by the

Energy Regulatory Act, Act No. 20 of 2004, is the corporate body mandated to have an oversight of the entire energy sector in Malawi (MERA 2016).

5.1.4 Policy framework for biofuels development

Malawi's biofuel programme predates the global move to biofuels. It is the only Southern African country with an operational biofuel market using ethanol from sugar cane that is blended into imported petrol (VON MALTITZ 2008). This was a positive response to the 1970s energy crises and the increasing cost associated with the importation of refined petroleum products for its transport sector mainly due to high transportation costs for a landlocked country. Biofuels sector development is regulated by the Liquid Fuels and Gas Act,

As part of the MERA 2014-2018 strategic plan, Goal No.3 *"enhanced conducive environment for security of fuel supplies"*, a biofuels strategy and guidelines were developed. This strategy recognised that security of fuel supply remained a major challenge due to among others over dependence on imported fuels and underutilisation and performance of the biofuels Sub-sector. This is very evident in 2012 when the country had no foreign exchange to import fuel to even conduct an important funeral for the late President Dr Mbingu Mutharika[20].

5.1.5 Jatropha development in Malawi

Malawi embraced Jatropha as a feedstock suitable for bio-diesel production. The main actor in the Jatropha was Bio Energy Resources Ltd (BERL) that adopted an out-grower plantation model using scattered small-scale producers. By 2011, BERL had contracted about over 20 000 farmers to grow Jatropha. BERL provided seeds mainly from wild Jatropha trees scattered around the country, training and extension support to out-growers during planting, management and harvesting. Farmers were organised in farming clubs of up to 15 members and were supported via extension services through trained field technicians employed by BERL.

The harvested seeds were purchased by BERL at agreed off-take price of USD0.15 per kg for A-graded seeds with farmer clubs and not individual farmers. A sophisticated

[20] I happened to be in Malawi in 2012 when there was a critical shortage of fuel and a German lodge owner pleaded to buy my extra 20 litres diesel for a ridiculous high amount.

logistical support was also installed that enabled farmers to communicate their yields within a 10km radius per farmer club.

BERL had set a target of up to six million litres of vegetable oil from Jatropha per year by 2016. Using a well-thought through decentralised production and support system, BERL minimised risks for its out-growers and the company.

5.1.6 Biofuels, food security and sustainability in Malawi

The issue of expansion of biofuels development is a sensitive one because Malawi's 90% of its export earnings is based on agricultural production output. With a relatively high population density of 140 people per square km and constrained by its landscape, 3.1 million families must derive their livelihoods from 6.5 million hectares.

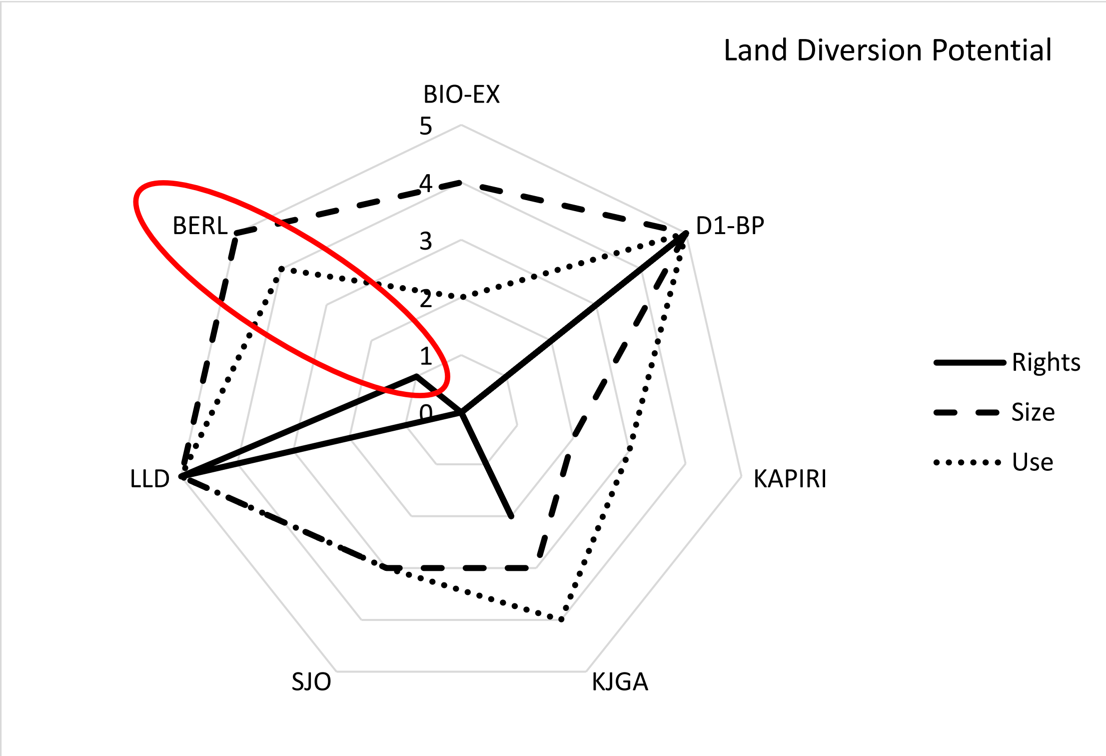

Figure 5-5: Land Diversion Potential: (Author's own)

Using the diversion-based evaluation framework, land diversion to biofuels in Malawi poses the highest sustainability risk as it has potential to harm food production and security. Malawi possesses enough arable land that can accommodate both food production and energy crop production. It is a question of increasing efficiency in the agricultural sector by utilising its irrigation potential and maybe diverting land dedicated for tobacco farming to energy crops. This can guarantee good market to the farmers since Malawi is net importer of petroleum and is the only SADC country which has a relatively well-developed value chain for blended fuel from ethanol.

Diverting land from tobacco farming to multiple products crops such as sunflower can not only improve the ecosystem by attracting bees (which have been affected by tobacco farming in Mulanje for instance) but can improve incomes for the farmers and enhance food security. It is a question of creating policies and conducive environment to unlock this potential and enhance sustainability in Malawi.

5.2 Namibia

5.2.1 Overview

Namibia as a country has its political history embedded in the apartheid South Africa that occupied the German South West Africa colony during World War 1 and administered it until World War II when it annexed the territory. In 1966, SWAPO waged a bitter guerrilla war for independence until 1988 when South Africa succumbed to international pressure to end its administration in accordance with the UN Peace Plan for the entire region. Namibia gained independence in 1990 and has successfully transferred power peacefully from one leader three times already via democratic elections.

Namibia is a vast and varied country of contrasting beautiful landscapes. It has a total land mass of 825 234 square km stretching between Latitude 17o S and 29o S and Longitude 11o E and 25o E. borders South Africa in the south, Botswana to the east, Angola in the north and Zambia in the further north east via the Caprivi Strip. In the east, it is lapped with a 1572 km South Atlantic coast line, claiming 200 nautical miles of strategic maritime territory. The landscape rises rapidly from the coast eastwards to inland plateau, most of which are above 1000 m above sea level. It peaks at 2579 m at the top of the Brandberg with central highlands around Windhoek to the south-west averaging at 1700m.

With a total number of people at 2.53 million (estimation by WORLD BANK GROUP 2017), Namibia is the second most sparsely populated country at 3.1 people per square kilometre, second only to Mongolia. This presents a challenge that is referred to a geographical periphery, which is administered in fourteen regions.

In terms of the economy, Namibia’s GDP is USD13.24 billion (2017) with a GDP per capital of USD 5227 (2017) and it was ranked 129 on the human development index (HDI) the same year, according to the UNDP HDI Report, 2017. It is classified as a middle-income economy, a status that presents a challenge to mobilise development funding to deal with the high-income disparity and achieve its development goals as per Vision 2030.

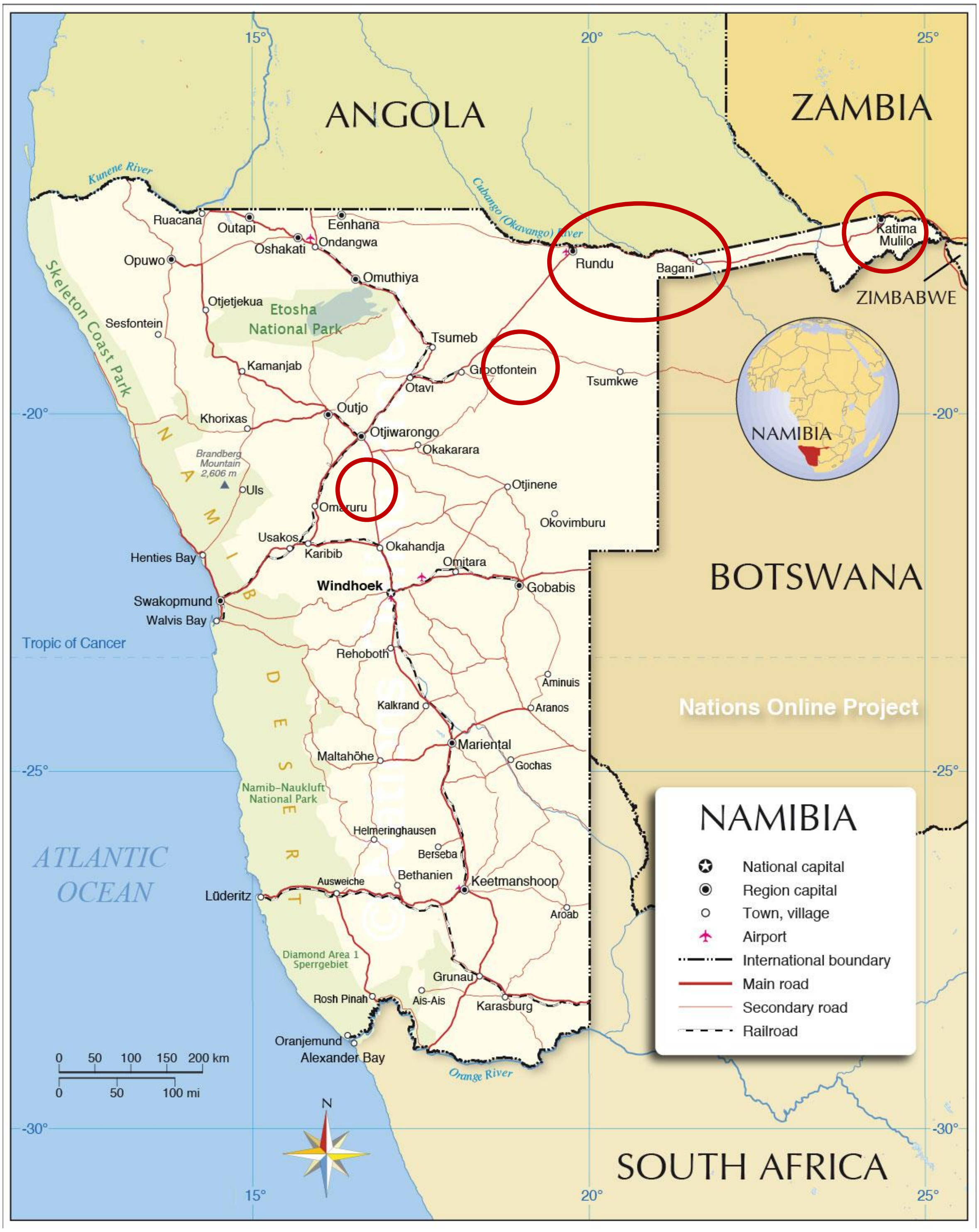

Figure 5-6: Map showing trial sites (red circles) in Namibia: (Source: Nationsonline)

5.2.2 Namibia agro-climate and production potential

Namibia is predominantly a dry and hot nation and its system of dry riverbeds indicates this. It has five perennial rivers at the borders with Zambia (Zambezi River), Angola (Kunene, Kwando and Okavango Rivers) and South Africa (The Orange River). The rest of the rivers that are inland are ephemeral and seasonal in nature.

Namibia as a country overall is classified as B climate with three distinct climates influenced by its latitudinal position and the presence of the cold Benguela currents. According to the Koppen-Geiger climate classification system, the three major climate types are the cool deserts (BWk) along the coast and south western interior; the warm deserts (BWh) in the south-eastern and north-western interiors; and the semi-desert steppe (BS) in the north and north east (GOUDIE and VILES 2015).

In terms of rainfall, Namibia shows great inter-annual and spatial variability. Amounts of rain vary in smooth gradient from wettest and most tropical areas in the north-east with rainfall range of 300-700m to the extremely arid Namib Desert in the west with precipitation range of 50-100mm. The major part of the country has single wet season in summer with most of the rain received between November and March each year. This type of low and variable rainfall pattern affects agriculture and other human activities (MENDELSOHN, JARVIS, ROBERTS, and ROBERTSON, 2002).

In terms of soils, the unconsolidated sand (i.e. arenosols) and shallow weakley developed soils on the bedrock (i.e. lithosols, xerosols, regosols and yermosols) characterizes the main soil groups in Namibia (FAO 1973). About 97% of the country has a clay content of less than 5% rendering the oil to be of low water retention capacity.

Considering the type of soil and very variability of rainfall, Namibia possesses only about 1% land surface (about 820 000 ha) that can be considered to have medium to high crop production potential. Most of this potential lies in the communal lands of the north-eastern country while a small portion of this is found in the commercial areas around Grootfontein-Otavi triangle and Stampriet near Mariental.

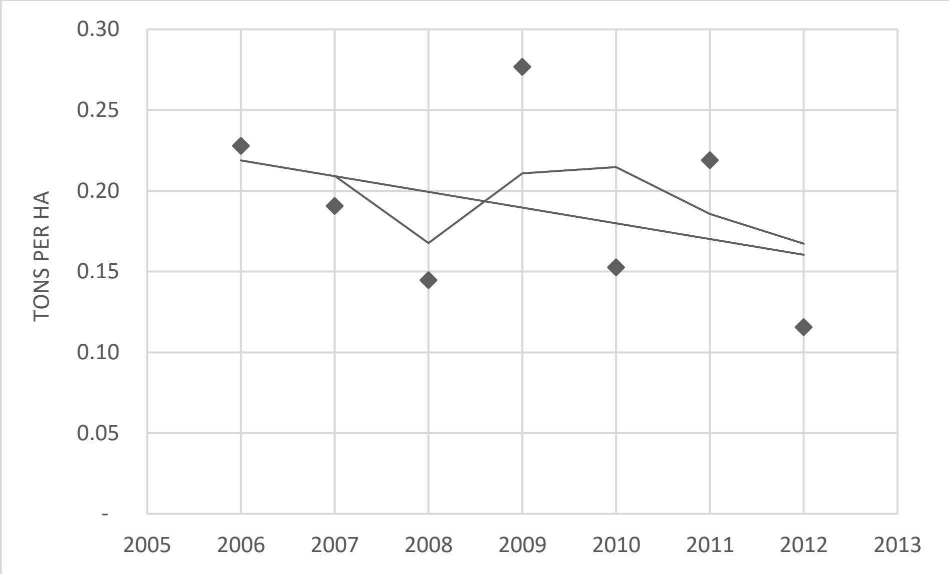

Figure 5-7: Namibia Cereal output ha^{-1} $year^{-1}$ 2005 to 2013: (Author's own, data FAO 2015)

Figure 5-7: indicates that there is a general decline of total cereal produced per hectare in Namibia. Reasons for this are several but research has indicated that the decline in soil fertility due to traditional agriculture practices and the impact of severe weather to be among the top influences. Expansion of crop land and increase in yields by adopting for instance conservation agriculture is considered as a strategic intervention to curb the declining output.

Table 5-1: Cereal crops planted and yields in Namibia in 2014: (data NSA[21] 2015).

Crop	Crop Area	YPH (MT)	Total (MT)	Households
Sorghum	7,043.00	1.24	8,733.32	24,646.00
Maize	34,991.00	1.60	55,985.60	17,620.00
Millet	421,212.60	0.97	408,576.22	129,029.00

[21] Namibia Statistics Agency

As for vegetation types, Namibia is grouped into Savannah woodlands predominantly in the higher rainfall north and east of Namibia while smaller succulents, grasses and shrubs dominates the desert and semi-desert areas in the west and south.

5.2.3 Namibia's Energy Sector

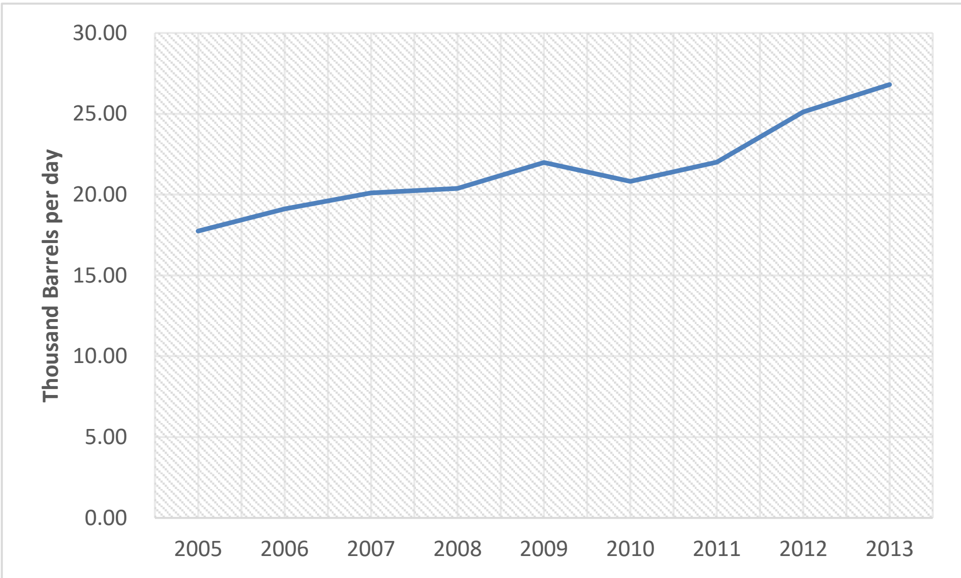

Figure 5-8: Daily petroleum Consumption trends in Namibia from 2005 to 2013[22]

5.2.4 Biofuels potential and risks in Namibia

The hype of Jatropha-based biofuel development did not spare Namibian. The study commissioned by SADC Secretariat and the quest to industrialise the rural areas motivated government agencies, NGOs and the private sector to consider biofuels development in 2005. Coupled with the constrained agro-climate potential in Namibia due to low rainfall and poor soils, it was believed that Jatropha as a plant presented a unique opportunity to curb further degradation of land and deliver the much-needed

[22] Produced from data from Namibia Petroleum Company, NAMCOR

rural employment while providing a source of renewable energy in form of biofuels to the communities.

In the absence of successful vegetable oil-based biofuels projects and programmes in the SADC region coupled with the potential risks of developing such, the Namibian government felt it did not have the competence needed to guide and steer this promising industry. The Ministry of Agriculture, Water and Forestry therefore, commissioned the Namibia Agronomic Board (NAB) to come up with a roadmap that may guide the government in the development of appropriate policies and strategies for a sustainable biofuels programme. NAB in consultation with key stakeholders, and in collaboration with some enthusiastic entrepreneurs, development the National Bio-oil Energy Roadmap. This was the first major effort in the country to development a framework for biofuels development.

A rapid assessment of the agro-climatic potential of Namibia against available options compelled the team to settle on annual oil-seed crops. Guided by available literature at the time, perennial crops were seen to possess the ability to rehabilitate degraded land and improve the chances of such land to provide certain eco-services. If such crops would produce the required amount of seed for a viable biofuels industry in such low agriculture potential environments, it would alleviate the competition for food production and avoid eroding the already stressed food security in the country.

Therefore, the roadmap identified Jatropha as one of the options as an additional cash crop with multiple by-products to supplement incomes of communal farmers especially and bring the much-needed relief to fuel importation.

Taking into consideration the size of the local market and the land conditions which are predominantly under communal land tenure, the following production models were envisaged for Namibia:

- Household model growing Jatropha as hedges around homesteads and crop fields for own consumption in the northern communal areas. The model was recommended as it had potential to mitigate against the rampant cutting of Mopane trees for fencing poles to protect both their homestead and fields.

The oil produce was to be used in special primus stoves that use pure vegetable oil from Jatropha for cooking. This then would reduce the pressure on Namibia's forests for firewood and charcoal and reduce or stop deforestation. House model is labour intensive and so planning Jatropha production requires careful planning of seasonal labour and so limiting the number of trees per household is a good strategy to avoid labour competition for other subsistence activities that could hurt food production. This model has potential to produce 8 000 to 10 000 ha of Jatropha. This model would rely heavily on the capacity of extension services from government and Aid agencies for technical and financial support to make it viable. It should be part of a bigger integrated natural resources management initiative.

- Community model: because of the nature of land tenure in the communal areas, a community driven model of growing Jatropha plantations was seen to be appropriate. This meant that community would go into partnership with investors by granting rights to utilise land in the communal areas via new land leases. This model would unlock the potential of those areas as it would attract investment, technology and knowledge requires to make the land productive. With careful planning, portions of concessional areas could be dedicated to food production thereby contributing positively to the national food reserve programme. This model would rely on effectiveness of community-based organisations (CBOs) assisted by NGOs and Aid agencies to make it viable.
- Out-grower model: Due to the nature of development and the fact that Jatropha was a new crop with little local knowledge, an out-grower scheme, like those for coffee in Malawi and Kenya, would be appropriate.
- Commercial farm model: This model involves development of Jatropha plantations by private local farmers using advanced agriculture technologies with irrigation capabilities. Production potential is dictated usually by markets with little reliance on the government for inputs. They exhibit high employment potential for local people and can also incorporate out-grower schemes to boost production if need be.

- Investor driven model: This model demands large land concessions given to investors to develop Jatropha plantations mostly in communal areas facilitated by government. The land concessions would bring the investing, agricultural and processing technology to cover the entire value chain. It has potential of creating a lot of jobs. This is due to the labour demands of Jatropha value chain especially during planting and harvesting as it cannot be mechanised due to continuous flowering and ripening over six months sometimes. Investor driven models have potential to displace and disposes land rights of local people if not properly regulated and may affect the capacity of the local people to produce their own food. The target in Namibia for this was concessions to produce up to 20 million litres of Jatropha oil per year.

5.2.5 Assessing Biofuels project initiatives in Namibia

The National Bio-oil Road Map identified six different types of risks in relation to establishing a vibrant crop-oil and biofuels industry. There were divided into three broad areas namely:

- Policy and regulatory framework failure; this posed to be one of the two top risks owing to the experiences in other countries that embarked on biofuels development. Appropriate policy and regulations to govern land tenure, land use and biofuel standards are crucial to stimulate and the development such a novel industry in the country
- Production and physical environmental failure; these two aspects are closely linked as production depends of the health of the physical environmental for Jatropha production. However, due to the limited knowledge of the seed production of Jatropha, external hazards due to extreme weather incidences may affect production, leading low yields and loss of markets.
- Social and market failures; as a new industry, ensuring markets for the produced oil is essential at two fronts. The first is economic impacts in terms of return on investment and sustainability of supply. The failure of markets may lead to loss of investment and loss of jobs and livelihoods. The second is the impact on the society in terms of livelihood and food security. A viable biofuels industry may require expansion of Jatropha production. This have

negative impact on people if displacement of the people due large land concessions is not avoided. Therefore, appropriate policy to ensure there is local economy to support this new industry is and avoid displacement and dispossession is crucial.

However, mitigating against the above risks does not guarantee that the Jatropha-based biofuels industry in Namibia would be sustainable with minimal impact on food security.

5.2.6 Okavango Jatropha Biofuel Project

In line with the National Bio-oil Energy Roadmap recommendation, Prime Investment (Pty) Limited mobilised investment of up to USD 50 million from the United Kingdom to implement a large-scale biofuels project in the Okavango Region of Namibia. The company planned to establish Jatropha plantations with the communities living in the area.

5.2.6.1 Physical environment and implementation model

The adopted model was to go into a business relation with the local people as an upliftment programme and not development aid. The area identified stretched from Katwitwi (west of Rundu) to Divundu (east of Rundu) along the Namibian section of the Okavango River. A factory was to be built in Rundu for extraction of seed oil, which then was to be trucked to a biodiesel plant in Walvis Bay, where the biodiesel would be blended and distributed as part of the diesel fuel stock. The extra would then be exported to the EU market.

To meet the projected demand of 22.7 million litres per year, the project intended to plant at least 63 000 hectares for a viable biodiesel industry. Plantations were to be established on identified 65 000 ha of former Kalahari woodland that was cleared prior to 1990 in order for the project to qualify and benefit from the Kyoto Protocol’s Clean Development Mechanism (CDM).

Three independent companies were established by the Holding Company (Prime Investment) to implement the project with the communities. A Farming Company, which was comprised of farmers was responsible for primary seed production from Jatropha. The Holding Company provided the required funding, technical support and seedlings from the nurseries that were established along the project area. The farmers, who were organised as part of the Kavango Jatropha Farmers Association (KJFA), contribute land and labour for the project. Prime Investment retained 60% shares in the farming company while KJFA held the remaining 40% on behalf of farmers. Each farmer received a certificate of ownership that guaranteed dividend payments from the profit of the Farming Company for the land and earn an income from the sale of seed. In addition, the farmers were to receive carbon credits dividends via the proportional shareholding that they had in the Farming Company.

The secondary company that was established was the Industrial Company that was to own the factories for seed oil extraction, processing of the oil into biodiesel, utilisation of the seed cake and other by-products. The shareholding of the Industrial Company reserved 40% shares from the start but were given opportunity to increase shares up to 49% in the processing company.

The last company was the Kavango Tractor Company that imported tractors and managed the seeds, fertilisers and provided transport for inputs to the farmers and seeds to the factory. The holding company was to provide financial assistance to the farmers if they wished to own and operate a tractor.

5.2.6.2 Impact on food security and Sustainability

The design of the Kavango Jatropha project was informed by a detailed environmental and socio-economic impact assessment that incorporated the draft sustainability principles of the RSB.

To minimise negative environmental impact, the project targeted the use of cleared and degraded land that was abandoned for crop cultivation. This meant that there was no clearing of trees for establishment of plantations and so negative impacts due to loss of land cover. A 200 m buffer zone from rivers and flood plains was enforced to safeguard wetlands and aquatic life against any potential pollution. In terms of conservation of carbon stocks, planting of Jatropha trees on cleared land meant that the carbon stock that was lost when the land was cleared would be restored. The potential sequestration was calculated and estimated at 116.7 metric tons of CO_2 per hectare per year. Another environmental benefit included utilisation of post-harvest material and biomass from pruning to improve soil fertility. Seed cake was also to be used in special design stoves and as bio-digesters feedstock and the sludge from this as fertilizer.

In terms of socio-economic status, the Kavango (combined east and west) Region was assessed as the poorest region in Namibia with more than 50% of its population classified as poor with 34.4 % rated as severely poor, according to the NPC Poverty Mapping Report of 2011. The agriculture sector is the main source of employment accounting for 60% of the employment in the region. The people depend on subsistence farming, livestock holding and cash remittances. Most households are still not able to provide adequate food for their families through crop cultivation and rely on off-farm cash incomes from a variety of sources. The income and expenditure surveys done by the NSA in 2010 indicated that up to 65% of the people of the Kavango regions showed consumption of food not grown by themselves showing that the economy of rural is shifting away from subsistence farming. With respect to food production and security, the project was not going to have significant impact on food production as it did not create land competition since the targeted 65 000 hectares were not utilised for food production. However, the share of labour needed to be managed to avoid labour competition for food and energy crop production.

The implementation of the Kavango Jatropha Project was a welcome venture as it promised to increase the income of the people by introducing a cash crop. Of the 24 000 households in rural Kavango, 8 000 – 13 000 families could potentially benefit from the project had the project reached maturity. The failure of this project therefore brought about a big negative socio-economic impact to the community.

5.2.7 Biofuel, food security and sustainability in Namibia

The development of biofuels in Namibia was motivated by the potential to increase rural agricultural productivity and income. The target market was the biofuel blending mandates set by the Europe Union via the Renewable Energy Directive No. 2009/28/EC. The targeted regions were mainly the Kavango and Caprivi[23] Regions due to favourable agro-climatic conditions and availability of cleared land in the case of west Kavango. The National Bio-oil Road Map estimated that 65 000 hectares would be needed to produce a total of 22.7 million litres of biodiesel to meet the national demand.

Apart from the nurseries and pilot plots, only a paltry 12 hectares of Jatropha was established in total in Namibia. The most promising was the four hectares of Jatropha that was planted at Shadikongoro Green Scheme (see Figure 5-8) as part of Prime Investment initiative.

The LLD Biofuels at Katima Mulilo Green Scheme planted six hectares and experimented with inter-cropping with sweet potatoes (figure 5-9). The health of the plants at the LLD biofuels project could not guarantee the estimated yields although the owners were optimistic that if government allowed Jatropha growing, they would expand to 10 000 ha on communal land that was pledged by the local chiefs.

The only out-grower scheme that was promising was in Ndonga Linena driven by a Shankara farmer[24]. He invested a lot of money to establish nurseries for Jatropha seedlings that were to be distributed to the out-growers. The out-growers were to join on a voluntary basis but once joined, the scheme was prepared to assist them to increase first their food output before embarking on Jatropha growing

[23] Caprivi Region was renamed to Zambezi Region by the Namibian Government
[24] The Shankara farmer did not want his name published in the thesis

Figure 5-9: A 2-year-old health Jatropha plantation at Divundu: (Author's own Dec 2010)

Figure 5-10: Jatropha intercropped with sweet potatoes: (Author's own May 2010, Katima)

Analysing the three case studies against the diversion-based evaluation framework revealed interested insights that are summarised as follows:

- Diversion of labour ranked highest. This is because Jatropha is labour intensive and it was estimated that for every hectare cultivated, two people would be needed while harvesting would require a double number of people at least and must be sustained for long periods. Managing the Jatropha and food production calendar cycles is recommended to avoid competition for labour needed for growing food.

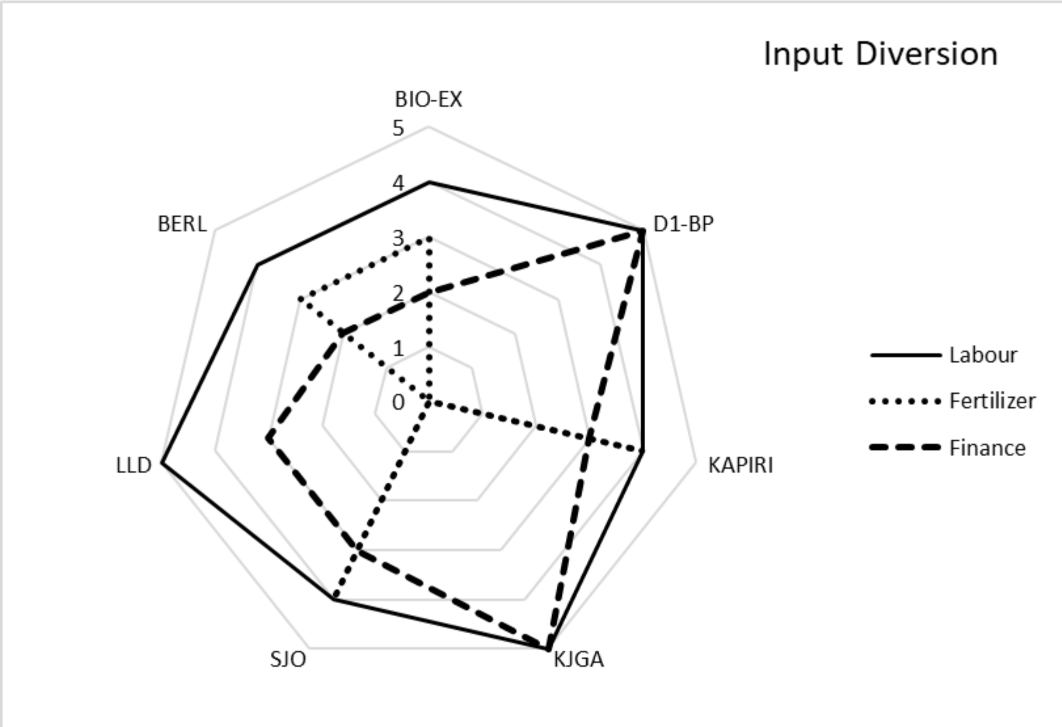

Figure 5-11: Input diversion score: (Author's own)

- Diversion of extension services: Jatropha as a new crop needed to be understood if it was to deliver benefits to the target beneficiaries and investors. It provides an opportunity to diversify land utilization and intensified agriculture extension. The Ministry of Agriculture, Water and Forestry (MAWF) would need to increase its already stretched extension services to accommodate Jatropha farming. This can be positive if the jobs created are attributed to Jatropha and increase productivity and income for participating farmers and target communities.

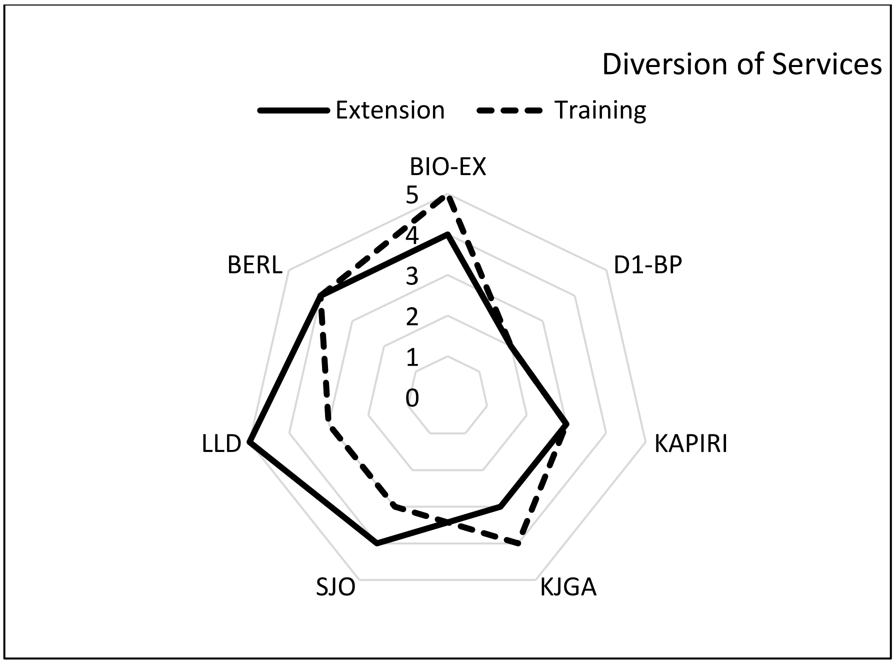

Figure 5-12: Service Diversion score: (Author's own)

- Land diversion was regarded as moderate but required deliberate interventions and monitoring to avoid induced diversion if growing Jatropha could have proven to be more lucrative than growing food crops. This is not necessary negative since increased income can lead to increase access to quantity and quality of food, hence contributing positively towards food security.

The question one needs to ask is: Why did the Jatropha projects fail miserably in Namibia and what were the impacts on the both the proponents and the local people?

Using the DBEF revealed that Jatropha projects did not fail because they were not designed or implemented properly. The killer factor was the absence of a policy and regulatory framework. For any biofuels value chain to thrive, an appropriate policy and regulatory framework is needed. At the time of Jatropha development in Namibia, a strategic environment assessment (SEA) was commissioned for the two regions that were targeted by investors. Although the SEA did not find any major environmental or societal negative concerns for Jatropha, the government decided to ban the development of Jatropha through a media announcement.

The absence of such a critical enabling environment for a potentially viable development was fatal to all the projects. It led to loss of confidence in biofuels related developments by the frustrated local community and major financial loses for the investors. Government in turn lost the potential tax revenues and cost reduction through import substitution.

5.3 Zambia

5.3.1 Overview

Since the 2001, the Zambian Government developed an enabling environment for investors that saw the booming of the economy, which saw the reduction of inflation from over 100% to fewer than 12% in 3 years. The refocus from donation to attraction of investment and the emphasis of the rule of law by the present government has led to Zambia to be termed the first stop for investors in the last five year.

Zambia is endowed with plenty of natural capital: lots of land (over 85% still virgin), good climate, good soils, water (40% of SADC total fresh water), friendly but hard working and well-educated people, good laws and a relatively efficient public sector. It has one of the most deliberate investor friendly policies in Africa, which allows investors to go on long tax breaks and also to externalise their profits.

Although mining is still the lifeline for the economy today with the agriculture, tourism and other service sectors posing a greater potential to transform this mineral rich but poorly managed country into a prosperous economy. Its GNI per capital stood at USD 3557 and was ranked 144 on the human development index (HDI) of 2017, according to the UNDP HDI Report, 2017.

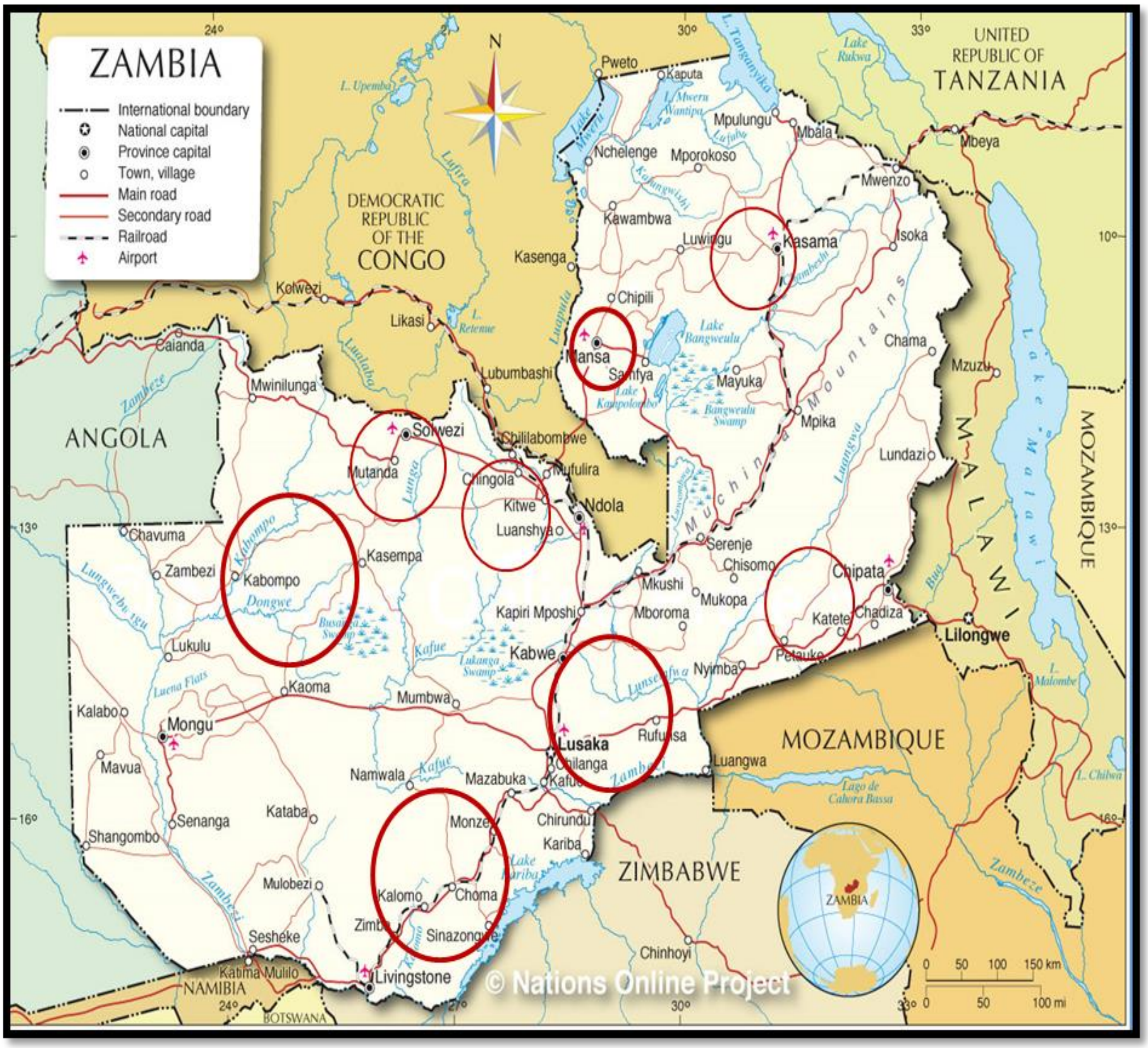

Figure 5-13: Map of Zambia with trial sites in red circle: (Source: Nationsonline)

5.3.2 Agro-Ecological Regions and production potential in Zambia

Zambia has a very high agricultural potential owed to the abundance of arable land and fresh water. It is divided into three distinct agro-ecological zones, differentiated by variable rainfall (MINISTRY OF AGRICULTURE AND COOPERATIVES 2004).

Region I: is the zone that receives less than 800 mm of rainfall per year and constitutes 14 % of the total land area. The soils are mostly clay rich and covers some parts of Southern Eastern and Western Provinces. This region also experiences droughts and floods but has high potential for livestock farming.

Region IIA: receives between 800 and 1000 mm of rainfall per year and covers 28% of the total land mass. It is characterised with fertile soils mostly along the line of rail, where majority of the white farmers settled in colonial days. It covers parts of Lusaka, Southern, Central and Eastern provinces. It is this zone that produces the most agricultural output and contributes over 50% to the national food reserve.

Region IIB: This region receives rainfall like Region IIA except that it is characterised by sandy and alluvial soils. It covers 12 % of the total land mass.

Region III: covers the high rainfall areas of Luapula, Northern and North-western provinces with an average rainfall in excess of 1200 mm per year. It is characterised by mainly heavily leached acidic soils and low fertility due to high rainfall.

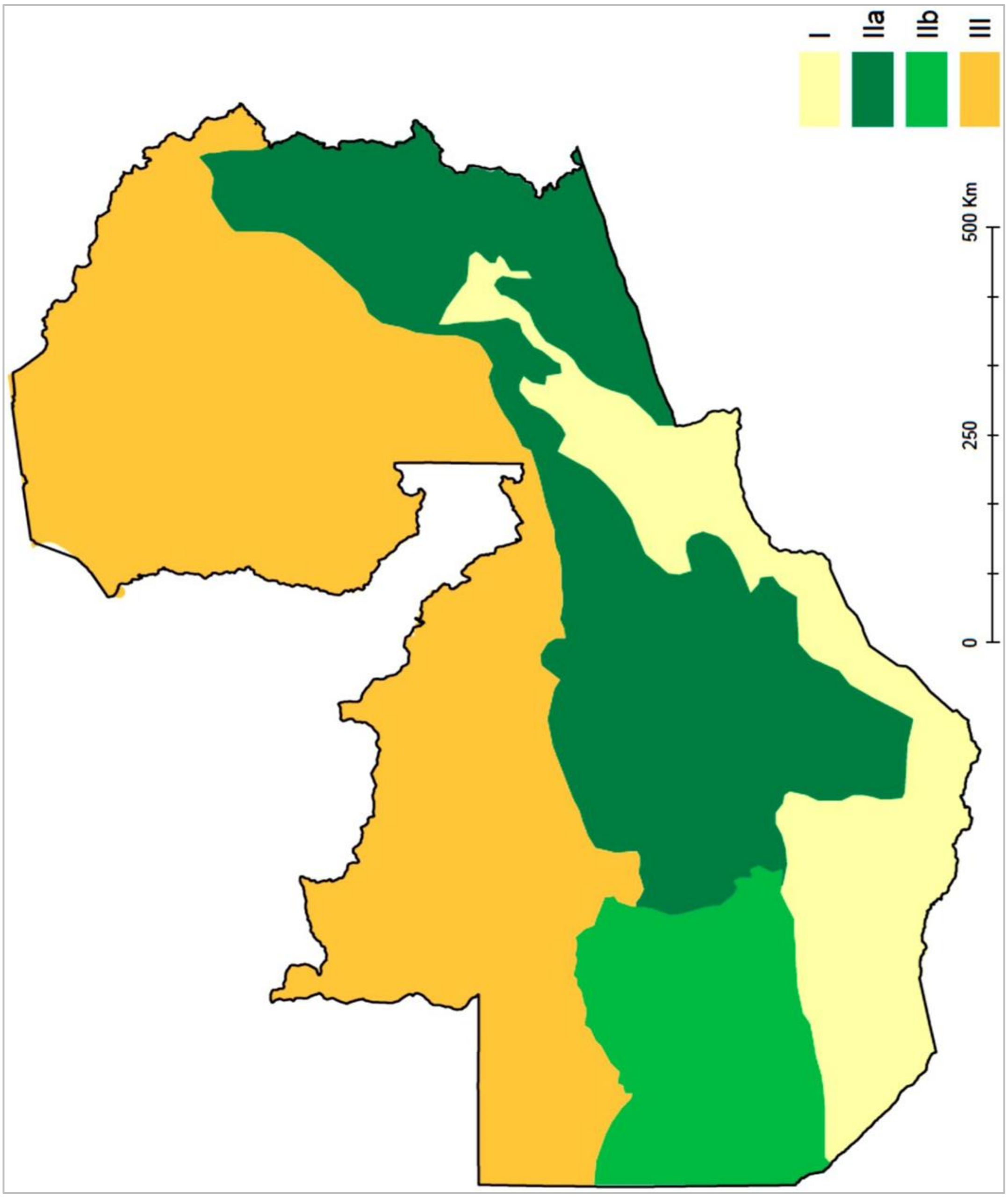

Figure5-14: Agro-ecological Regions of Zambia: (Courtesy of Ministry of Agriculture)

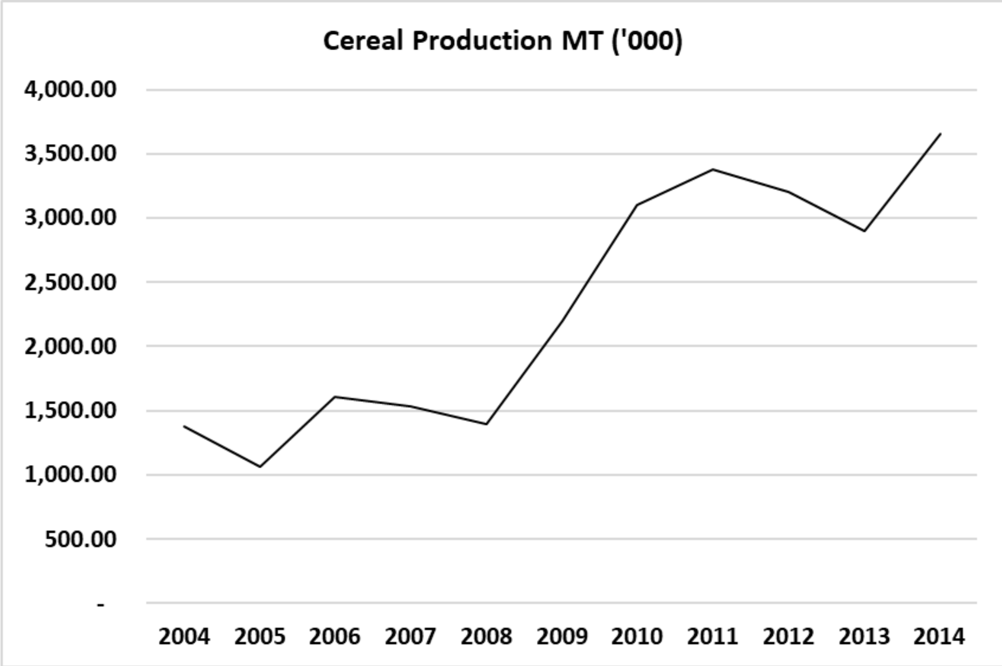

Figure 5-15: Cereal Production trend in Zambia 2004-2014: (Author's own, data FAO 2017)

5.3.3 Land tenure regime in Zambia

In terms of land administration, land in Zambia is vested in the president. It is divided into two many categories: statutory land and customary land. Under statutory, land rights can be registered in form a lease of maximum period of 99 years. This is the highest form of tenure security possible. On the other hand, traditional land, which covers most of the so-called trust lands, can be perpetually held under customary law. There is a possibility to convert land from customary to statutory but not vice versa, a condition that has raised a lot of resistance especially by the chiefs. The Lands Act (1995) makes provision for such but the procedure is not as simple in practice as it is on paper (CHILESHE 2005).

Under the current system of tenure, Customary Land[25] constitutes about ninety percent (90%) of the total land area of Zambia, which is seven hundred and fifty-two thousand (752,000) square kilometres while State Land constitutes only 10 percent (10%) of the total land area.

[25] Customary land was before independence composed of reserves and trust lands established by the colonial master.

A lot of land that is being targeted for bio-fuels development is therefore not surprisingly mainly customary which is not formally recognized by the financial system. Development of a vibrant bio-fuels industry will require a favourable land access system that benefits the local people but at the same time encourages the much-needed investment without leading to “land grabbing”.

The process involves identifying a piece of land and obtaining permission from the chief in the area after consulting his subjects whether bringing in an investor into the community is beneficial. Armed with a consent letter the investor can then engage the land use section of the Ministry of Agriculture to do a land evaluation to create a suitability map. A course accuracy map of the piece of land is then prepared and an application for allocation submitted to the Ministry of Lands. Once approved, it is numbered a 14-year lease tenure is offered with conditions to develop the land to a particular value. The applicant is expected to comply to this condition subject to availability of enablers. The applicant can choose to apply for a 99-year leasehold, but this requires the land to be demarcated by a licenced land surveyor. The applicant in this case engages a land surveyor to carry out a cadastral survey to produce diagrams, which are then used in the application for a 99-year lease which is registered through a title deed. Shorter leases are possible as a means of protecting sovereignty and degree of control by the government.

5.3.4 Petroleum energy and biofuel sector

Since time immemorial Zambia has been a net importer of all its petroleum requirements that represents 9% of the total national energy demand. It is used mainly in the transport sector and a small percentage dedicated for thermal power plants in remote areas that are not linked to the national grid. The transport, mining and agricultural sectors are the major consumers of liquid fuels (REPUBLIC OF ZAMBIA 2008).

The petroleum is supplied via a 1700 km pipeline from Dar es Salaam in Tanzania to Ndola, on the Copperbelt Province, where the only refinery of Zambia with a total capacity of 1.1million metric tons/annum is located. It is from this facility where LPG, HFO, Gasoline and Diesel are produced and distributed throughout the entire country by Oil Marketing Companies (OMC) (Republic of Zambia Ministry of Energy and Water Development (MEWD 2008).

Therefore, one of the major challenges of government is to meet its ever-increasing energy demand for industrial development, commercial and domestic purposes. Demand for liquid fuels coupled with the increasing conscious of global warming impacts and the quest to deliver on its promises of developing the rural areas, the government is encouraging investors to develop projects that have potential to address most of these challenges.

The government is particularly attracting investors in the potentially lucrative bio-fuels sector using different alternatives. Sugarcane and JCL are the most favoured feedstock crops due to low competitiveness to food production and potential for multiple uses.

In order to facilitate the development of the biofuel sector, the Zambia government has developed a policy that currently is being drafted into appropriate regulations to create incentives for investors to venture into this new sector. The Biofuel Association of Zambia (BAZ) was tasked among others, to attract foreign investment into this sector.

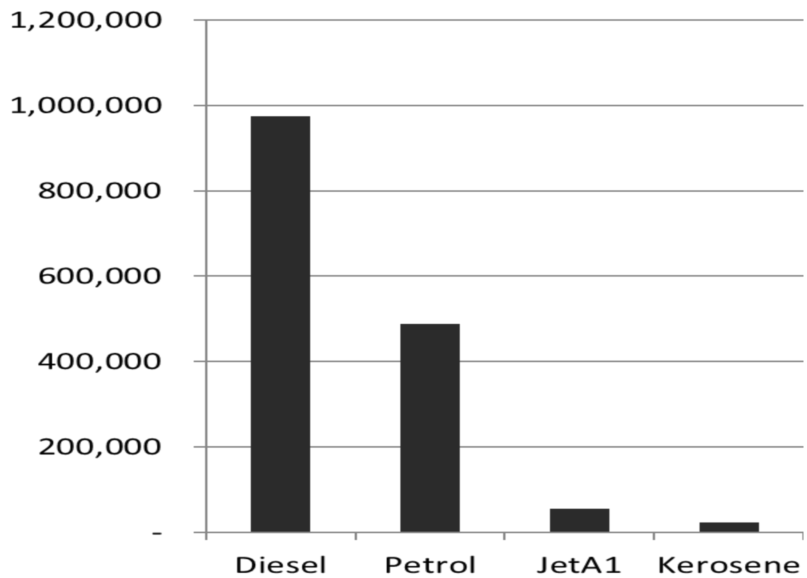

Figure 5-16: Fuel consumption in Zambia in 2011: (MEWD 2011)

In terms of consumption, the transport sector takes about 53% while the mining sector consumes 27% of the total production. Of this there is no contribution by biofuels as this sector is in its infancy except of some very few self-consumption projects. The figure below shows the consumption of petroleum per sector (MEWD, 2011).

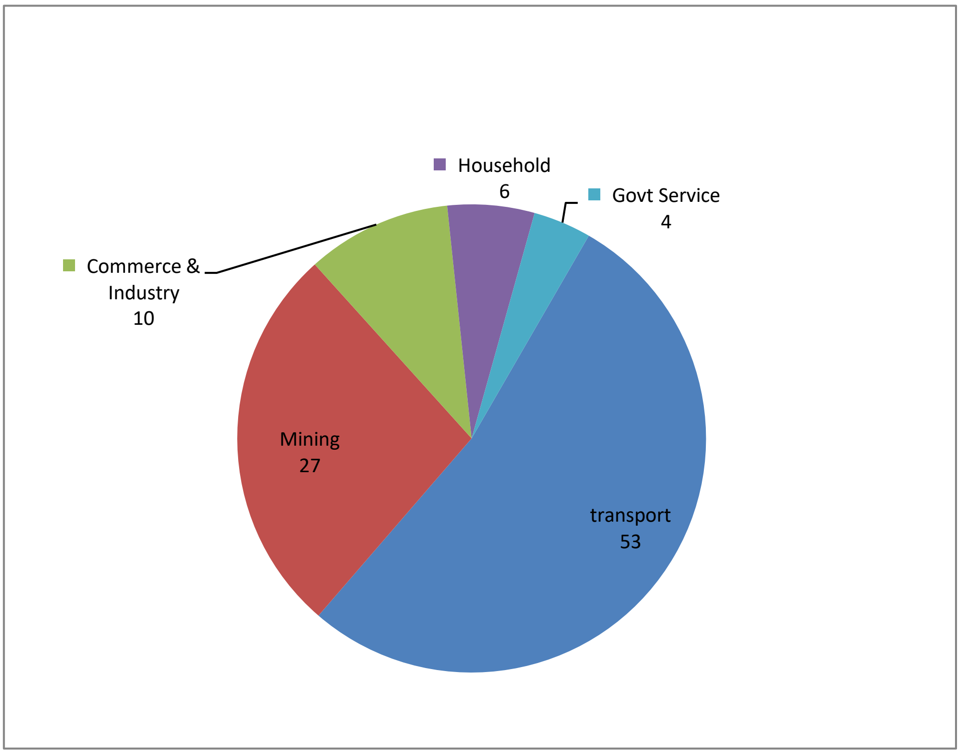

Figure 5-17: Consumption of petroleum fuels in Zambia: (MEWD, 2008]

5.3.5 Jatropha based biofuels development in Zambia

The Zambian government is aware that in order to have a sustained economy growth that currently oscillates at 6% GDP growth per annum, it is important for the country to have a sustainable energy supply that includes a very vibrant liquid fuels sector. While the main driver for biofuels development in the developed world is to curb greenhouse gas emissions responsible for global warming and climate change, the main driver in most developing countries in Sub-Saharan Africa is energy security, employment creation and rural development (MEWD 2011).

With the recent sharp fluctuations in the crude oil prices and the increasing instability in the oil producing countries, the Zambian government has identified the importance and significance of biofuels potential to contribute to energy security in the country. This is evidenced by the development of a Bio-fuels Industry Strategy and the inclusion of biofuels sector in the National Energy Policy of 2008. The recent pronouncements of voluntary blends by the Minister of Energy and Water Development, is a major indication that the government is ready to develop this young but important industry in Zambia.

The National Energy Policy identifies biofuels as part of the national energy mix that currently is dominated by the use of biomass in terms wood fuel. Wood fuel is responsible for some 70% of total energy consumed in the country especially in rural areas and urban poor communities. Although Zambia is endowed with a very rich landscape covered by woodlands and forests, with the growing rate equivalent to 4.3 million tons of wood, dependence on this energy source poses a major threat to national forests as consumption has over stripped regeneration rates of the indigenous forests (MEWD, 2008).

Finding alternative sustainable energy supply that can be accessible even in remote areas is one of the drivers of developing the biofuels sector.

5.3.6 Institutional Framework for biofuels in Zambia

The development of the biofuels sector was driven by the Ministry of Energy and Water Development (MEWD) and the private sector through the Biofuels Association of Zambia (BAZ). The National Energy Policy provides the general guidelines for the development of the biofuels sector while the National Biofuels Industry Strategy Paper adopted by the MEWD in 2008 provides the specifics of how the country wants to develop the sector. In terms of legal framework and the absence of the biofuels act and regulations, the sector is regulated by the petroleum, petroleum production and exploration and the energy regulation Acts while the Environmental Protection and Pollution control Act performs a watch dog mechanism to ensure the development of the industry is environmentally sound.

The Statutory Instrument no. 42 of 2008 provided the basis for inclusion of biofuels on the Energy Regulation Act. It gives power to the Energy Regulation Board (ERB) as the agency to regulate production and utilization of biofuels. In terms of standards, Zambia Bureau of Standard has included the ZS E 100 and ZS B100 standards for ethanol and biodiesel respectively.

Although the development of the biofuels industry in Zambia is squarely driven by the MEWD, it needs to interact with other legislation pertaining to land, environment, agriculture, labour, commerce and industry and other human rights.

5.3.7 Choice of feedstock

The draft Biofuels Industry Development strategy paper identifies six major sources of feedstock for biofuels production. For Ethanol, molasses coming from Sugar factories, cassava and sweet sorghum are the feedstock preferences in Zambia. Maize although produced in surplus has not been considered since it is the stable food of the country and diversion of maize to biofuels can cause a negative effect on food prices.

As for biodiesel, palm oil, Soybeans and Jatropha have been identified as the potential crops to provide the feedstock. Sunflower, being a food crop, must be approached with caution to avoid competition with animal feed production and vegetable oil for human consumption. Since the entire primary production is agro-based, the National Agricultural Development Policy plays a significant role in the development of this agro-based bio-fuels industry.

Table 5-2: Land demand for 1.5 billion litres seed oil in Zambia: (Data World Bank 2013)

1.5 billion litres Feedstock	**Yield/Ha**	**Needed Land (in Ha)**
Palm	4,803	312,305
Groundnut	2,610	574,713
Jatropha	1,800	833,333
Sunflower	796	1,884,422
Soy	686	2,186,589
Castor	489	3,067,485

5.3.8 Land, food security and Biofuels

The greatest potential that Zambia has is her arable land and its rich natural resources (especially mineral deposits). The Government has recognised the importance of this comparative advantage in the development of a strong and prosperous nation. The heavy reliance on mineral exports has proven in the past to pose risk to economic growth as in times of depressed prices, the whole economy suffers a lot. GDP growth drops as low as 4% during times when the price of copper, the main mineral export, are depressed.

Zambia is endowed with a good agro-climatic condition with abundant arable land and over 50% of total water resources of the SADC region. At present the country uses only 14% of the total arable land of approximately 42 million hectares (DFID 2001). The water resources that provides a huge potential for irrigation is currently underdeveloped with only about 65 000-ha developed under irrigation which is less than 15% of total potential.

Although Zambia produces surplus maize, about mean value of 2.4 million metric tons estimated per year, (FAO 2017). Majority of this production is by micro-scale (commonly referred to as peasant) farmers. This is a very labour-intensive practice and therefore contributes about 60 % of the total labour force in the country.

However, the agricultural sector is extremely inefficient leading to low productivity per hectare. Although there is plenty of arable land, the sensitive of the agriculture sector demands policy coordination between the energy and agriculture sectors to avoid negative impact on food production and food security.

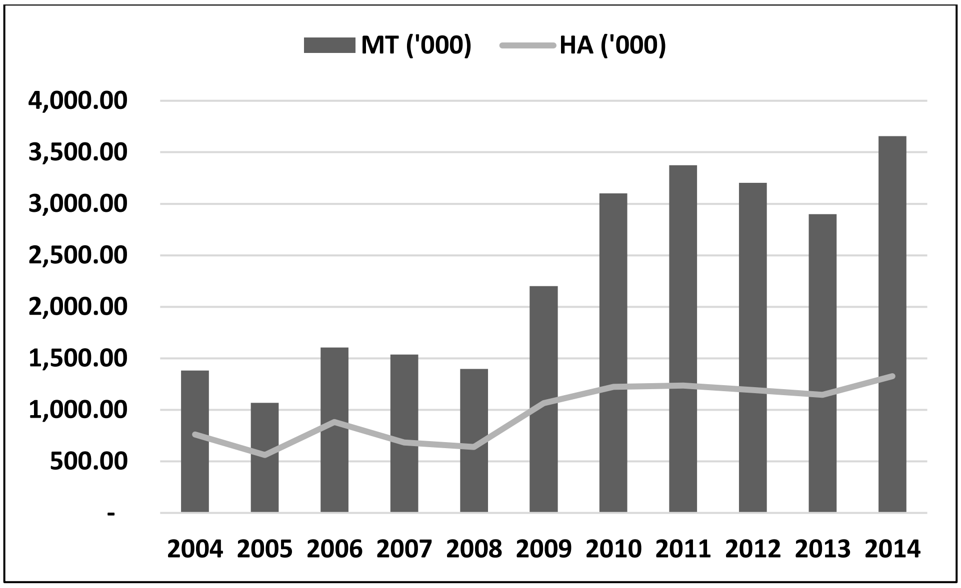

Figure 5-18: Planted area versus cereal yields in Zambia: (Author's own, data FAO 2017)

5.3.9 Market potential for Biofuels

The announced blending ratios and the biofuels regulations and standards (Ministerial speech, MEWD, 2010) has unlocked the biofuels market in Zambia. With about 1.0 million metric tons of diesel consumption, the 5 % blend provides some 250,000 metric tons assuming blending is mandatory. With the increase in mining and agricultural activities which subsequently pushes demand for transportation and energy, the market for biofuels promises an upward trend.

Despite the announcement of the blending ratios that was a major bottleneck in the development of biofuels, there is no project that is producing biofuels on a commercial basis. We may see an increase in investment in future, but alignment of other sectors would be crucial to the development a sustainable market and infrastructure. There is still a lack of blending infrastructure at the only refinery and national storage facility in Ndola.

5.3.10 Case study: D1_BP Oil Joint Venture

The quest to meet the increasing demand for biofuels globally triggered interests from major fuel producing and marketing companies. BP is one such company that is rolling out a major plan to develop feedstock production system across the globe. BP and D1 Oils Africa have formed a joint venture company D1-BP to develop Jatropha plantations in Zambia to provide the feedstock for bio-diesel production.

The two the main Jatropha Plantations that D1-BP Oil established were Rufunsa, situated about 100km east of Lusaka, and Kachumu, some 120km South West of Kasama.

The Rufunsa farm was situated on a piece of land that has been allocated by the local chief to the project, with the facilitation from the government. It was difficult to establish the status of the land rights as there was no documentation that could be used to confirm any agreements in terms of land tenure rights. The absence of a map made it difficult to see the spatial relationships between the farm and the surrounding villages and the adjacent game management area. The farm had employed, one qualified farm manager, two senior farm officers, twenty supervisors and over six hundred and fifty casual workers. The minimum wage being paid for a farm worker was K11.2 (about USD1.2)[26] per 8-hour day shift.

The Kachumu farm is situated in the Northern Province. The farm had attracted a considerable number of people from neighbouring villages and towns. A proposed workers compound has expanded into a little village that is across the stream that supplied irrigation water for the farm. Kachumu farm was managed by a farm manager employed from South Africa with a total workforce of 1026. The farm manager was represented in the field by 30. In terms of wages, the minimum wage of K11.20 at Kachumu for a general farm worker was implemented. Nursery supervisors, field supervisors and administrative officials get a slightly higher income of between K18.00 and K26.00 per day.

[26] Rate used: 1 USD = K9.33 (rebased) in 2011. It is now oscillating at K11.92 to 1 USD source: www.xe.com accessed 03.02.19.

5.3.11 Jatropha development by BIO-EX in North-western Zambia

Production system in BIO-EX was organised in farming zones. In Kisalala zone area in Mbambiko village, had 65 contract farmers under Bio-ex project, of which 12 were women. Of the 13 farmers interviewed, one farmer confirmed that to have land size of 24 ha under customary land tenure. The table below summarized the land ownership and the number of Jatropha planted. The farmers indicated that they had knowledge about Jatropha as an ornamental plant but not its use and economical value as they know it today.

Table 5-3: Size of Jatropha plots in Bio-ex in Zambia: (Author's own)

Land Size (ha)	No. of farmers	Jatropha planted
Less than 10	6	500 (i.e. 1 ha at 5x5)
10 – 20	6	500 (i.e. 1 ha at 5x5)
Over 20	1	1600 (i.e.3 ha at 5x5)

In terms of income from other crops, the interviewed farmers indicated that millet gives the most income as it is processed into a local beer that sells better and for a longer time of the year, depending on the amount harvested. Of the interviewed farmers each farmer earned an average K3.5million per annum (equivalent to USD700/yr.) from different farming activities.

When asked whether they have benefited economically from the project, most farmers indicated that it was too early to indicate this but were disappointed by the perceived low price of Jatropha offered by NWPB. At the same time, several of the 13 farmers indicated the willingness to expand their Jatropha cultivation and some have set up nurseries in readiness for the next season.

The main complaint that was heard was the labour demand of Jatropha. Farmers indicated that they had to divert labour to tend to the Jatropha plants especially for weeding and pruning. Those that have harvested indicated the tedious and laborious picking and shelling process. This in their opinion poses a potential labour competition with other crops especially if they expand their Jatropha fields.

In terms of training, farmers in this area expressed their disappointment that despite the promise that training would be given, they only received seeds and/or seedlings and not the promised training and field extension services. However, during meetings, tips on how to look after the plants like pruning and weeding were given. Basic knowledge about use of agriculture waste coming from Jatropha and other crops as composite fertilizer was conspicuously absent.

5.3.12 Market development in Bio-ex

North West Bio Power (NWBP) and SNV were responsible for the organization and development of the mechanism to support Jatropha market development. The contract signed between NWBP and the farmers was aimed at guaranteeing a market for the Jatropha seeds at the agreed price of 8% of ruling diesel price. At the time of the visit, this worked out to be less than K0.50 / kg although NWBP was buying at a high price of between K 0.65 and K1 per kg.

As indicated earlier, over 8000 out-growers were recruited but only a few of the interviewed farmers indicated to have sold their first yields. The out-growers spoken to indicated that the price being offered for a kg of Jatropha seeds is below their expectation. This expectation could not be established well but was based on a mere comparison of Jatropha seed price to maize. Some even kept some seeds in anticipation of a higher offer later on. However, when compared to the other crops' producer prices as shown in the table below, Jatropha price per kg did not compete well in terms of gross income. This price discussion, however, needs more analysis and information sharing for the farmers to understand the pricing structure of the Jatropha seed.

At national level, the announcement of biofuels blend percentages and targets has created the much-needed market for biofuels due to sudden demand created to meet these targets. Market development requires that all stakeholders ranging from government, private sector, development partners, the farmers and regulators work together. The strategy that was adopted in Bio-ex could have been more effective if there was deliberate engagement of stakeholders to address issues related to pricing and logistics in particular. Working closely with BAZ, Energy Regulation Board and MACO would have improved these aspects. Such alliance would have assisted in pushing government to implementing some of the incentives as proposed in the Ministry of Energy and Water Development's Biofuels' Industry Strategy adopted by cabinet in 2008. Perhaps this will happen in the new future as compulsory blending targets are implemented and may change the entire biofuels and agricultural landscape.

Table 5-4: Price of different crops in Zambia 2011 (Data Provincial Agriculture Coordinator[27])

Crop	**Price (USD / kg)**
Beans	1.25
Cassava	0.42
Groundnuts	1.04
Jatropha	0.14
Maize	0.23
Millet	0.42
Sorghum	0.42
Sweet Potatoes	0.35

[27] North Western Province, Provincial Office in Solwezi, Zambia

6 Sustainability of Jatropha production in SADC countries

At the hype of the biofuel and food security debates, the SADC region commissioned a feasibility study to look at the potential to produce and utilise biofuels. The study followed recommendations of the SADC extra-ordinary summit that was held on Agriculture and Food Security that noted that poor access to markets was proving to be a major barrier to the agricultural development and to achieve food security. A joint committee of senior officials of food, agriculture, natural resources and infrastructures and services from SADC region agreed at a meeting in Gaborone in 2004 that biofuels initiative presented an opportunity for the region to produce and utilise its fuels from renewable resources.

This together with the pronouncement of EU blending targets formed the basis for member states to embark on biofuels development programmes. This was seen to be in line with the SADC Regional Indicative Strategic Development Plan (RISDP) and was consistent with the quest to reduce GHG emissions at global level.

6.1 Diesel demand in the SADC

The transport sector in the region relies almost 100 % on fossil fuels imported mainly from the Middle East despite having abundant oil reserves in Angola and Mozambique. Landlocked countries like Botswana, Malawi, Zambia and Zimbabwe suffer from high cost of fuel owing to high cost of transportation and related logistics. Despite the increase in pressure to mitigate GHG emissions and climate related impacts of the transport sector coupled with the push to unlock the potential of the rural areas, the SADC region biofuels development programmes have lagged behind other aspects of renewable energy (SADC 2015).

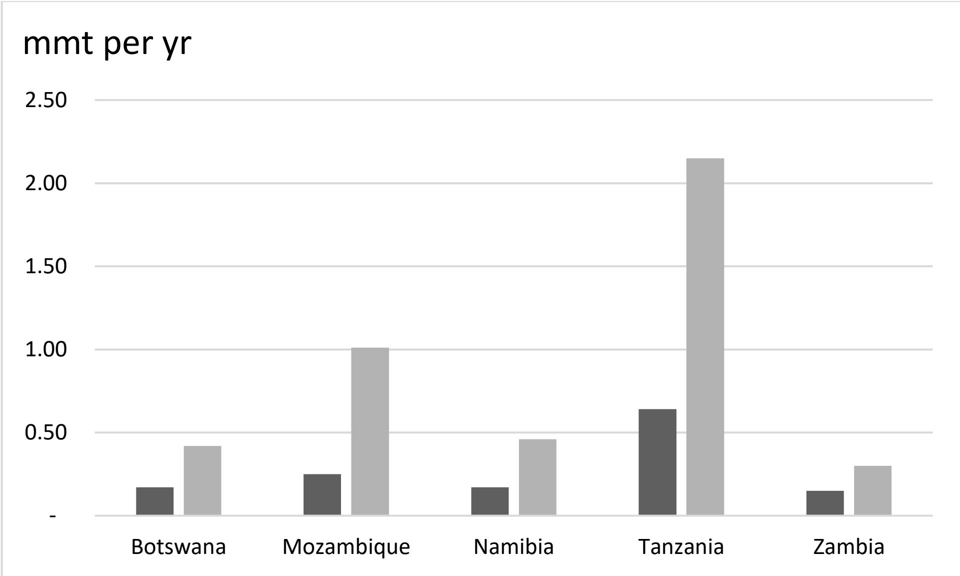

Figure 6-1: Projected diesel demand in selected SADC countries 2005-2020 (Data: SADC 2015)

6.2 Biofuels development in SADC countries

The reasons for embarking on biofuels development by a country or region are many. In the EU biofuel is driven by the commitment to reduce GHG emissions that are responsible for global warming and its impacts. In contract, the primary drivers at national and regional level in the SADC region are not necessarily related to global warming except for South Africa. South Africa is the 12th largest emitter of CO2 in the world and is responsible for nearly 50% emissions for the entire African continent and 1.6% of the global total. About 69% of RSA emissions come from the power sector that relies heavily on coal.

The following presents a summary of the main drivers of biofuels development in the SADC region:

- Import substitution: Most SADC member states are net importers of liquid fuels except for Angola and DRC.
- Commercialisation of agriculture and diversification of the rural economy by linking farmers to the energy sector that could provide a lucrative market for their produce and therefore generate employment

- Foreign exchange savings through import substitution since most SADC member states are net importers of liquid fuel. The saved funds if utilised appropriately have potential to stimulate economic growth and poverty reduction
- Enhancement of energy security at local, national and regional level (in the transport sector mainly)
- Contribute to curbing of deforestation and degradation of the agricultural ecosystems by adopting non-food crops like Jatropha and non-cereal crops like palm oil

	Ethanol	Feedstock	Agro-system Fit	Socio-economic potential	Production Scale	Concerns	Country
1		Sugarcane	Minimum 600mm rainfall, widelygrown, potential for expansion	Technology well stablished, bagasse usale, ethanol blending taking place	Commercial, outgrower	High water demand,	All except Namibia and Botswana
2		Sweet Sorghum	Low water required, thrives in 250mm rainfall, drought tolerant, adapted to marginal condition	Best food-fuel potential, fits ethanol processing, variety of use	Commercial, smallholders	Crop not fully developed, low yields may affect viability	All, best for drier countries
3		Maize	Well adapted, high agronomic demands, drought vulnerable, high water demand, high input	Wide spread, technology for ethanol well established	Commercial, cooperatives, smallholders	High Food-fuel conflict, grain price may affect viability	All, limited in Namibia, Botswana
4		Cassava	Grown widely, drought/flood acidity, salinity tolerant, low input	potential for expansion, high yields, important food crop, multiple uses, less competition for good soils	Commercial, cooperatives, smallholders mainly	Need more research, promotion needed	All but little in Namibia, Botswana
5		Sugar beet	Crop grows widely, well adapted to region	Similar and high output like sugarcane,	Commercial, gardens	Ned awareness, knowledge gaps, need for improved varieties	South Africa, Zambia, Zimbabwe, Mozambique
6		Sweet Potato	Well know at small scale, well adapted, low input, less labour	40-50% more start than maize, 3x more yield than maize,	Mainly smallholder	Technology gap, need improved varieties	All but big in Zambia, Mozambique, Malawi,
	Biodiesel	**Feedstock**	**Agro-system Fit**	**Socio-economic potential**	**Production Scale**	**Concerns**	**Country**
7		Soybean	Well adapted in region, Little/No nitrogen needed, moderate water demand	Multiple and High value products, relativel low yields/ha low biomass	Commercial, outgrowers, cooperatives	low smallholder participation	All, limited in Namibia, Botswana
8		Sunflower	well adapted and known, good for bee population	low yields 1.5t/ha, high value oil	mainly commercial, smallholders	Low yields, high value, suited for table oil	All, but limited in Namibia and Botswana
9		Ground nut	Well adapted, no nitrogen, moderate rainfall required, high labour input	high yields, high potential, multiple high value products, extraction techology known	Commercial but mainly smallholders	High nutrition value, expensive,	All, limited in Botswana and Namibia
10		Jatropha	Low rainfall, broadly adapted, perennial, used to curb deforestation, not frost tolerant,	potential for high yields and oil content, mutliple use, low	Commercial, outgrower, smallholder	Yields unknown, claims of low input doubts, need new varieties, labour intensive,	Not commercially grown in most countries, banned in RSA, Botswana and Namibia

Figure 6-2: Biofuel feedstock's implications in SADC region (CHAKUYA 2009)

6.3 Competing interests: Food security and energy Security

Energy and food security, key issues that motivated the formation of SADC, remain critical development challenges to this day. Expanding access to modern electricity for domestic use and other local needs has become an urgent priority. This is because some 70 % of people in DRC and Malawi, 60 % in Mozambique, Tanzania, Zambia and Namibia still depend on fuel wood (SADC Report 2015). This dependence on biomass for energy is threatening the natural forests. As a result, the SADC region has become a key player in the development and deployment of renewable energy technology as well as introducing relevant policies and programmes to encourage energy efficient technologies to meet both its needs and mitigate against deforestation and general environmental degradation.

The issue of food production and security is a very sensitive one especially in countries like Zambia where the targeted out-growers are responsible for over 75% of total food production in the country. Bio-ex was designed to supplement income of the subsistence farmers by introducing a cash crop in their farming system. Several diversions that can lead to reduction in food production in the communities were identified and observed.

6.3.1 Diversion of arable land

Diversion of land meant for food production to Jatropha, leading to reduction in the amount of land available to grow food. In Bio-ex, the issue of land diversion was extremely minimal as most farmers interviewed had more land than they could possibly use. They underutilized at least 50% of the total land they possessed. It meant that Jatropha growing was done on excess land that each farmer had. In order to avoid land diversion, this extra land need to be managed and monitored very closely and hence the need for good extension services. In this sense Bio-ex did not cause reduction in land meant for food production.

Another aspect that can be drive land diversion is foreign direct investment (FDI) in biofuel crops. China was negotiating for five million acres in Zambia to grow Jatropha (Amigun, Musango and Stafford, 2011). The large-scale mechanised production of energy crops has become a big concern in most African nations, as there is tendency to accelerate further land grabbing by richer nations facilitated by a recipient African government.

6.3.2 Diversion of labour

Diversion of labour and other production tools to Jatropha and thereby creating labour conflicts with food production. In Bio-ex, this seemed to have been a major concern by the farmers. They expressed the tediousness and laborious aspects demanded by Jatropha from the time it is planted until harvesting. It seems to be competing with maize harvesting for example during fire-breaks creation and weeding. Harvesting, especially husking, seems to compete with other domestic and farming chores like food processing and harvesting sweet potatoes, beans and millet. This therefore could have led to the losses that the communities visited expressed. However, this needs to be analysed further to avoid making uninformed conclusions.

6.3.3 Diversion and or dilution of finance

Diversion and/or dilution of finances to Jatropha. This means savings earned from other activities can be diverted to Jatropha for land preparation or input procurement as an example. This was evidenced in the amount of money spent on labour hire for weeding and husking. Bio-ex did not make any provision for appropriate manual husking tools that could have reduced labour input. This diversion has had a negative net effect in some cases when the average income of interviewed growers reduced by at least 40% due to diversion of income.

6.3.4 Impact on food prices

In their study, AMIGUN ET AL. (2011) showed that increased demand for biofuels was responsible for about 30% of the weighed grain price increase from 2000 to 2007. Many Africans spend over 50% of their share of income on food and many African countries import food to meet their domestic energy demands. In the year 2000, the average total imported cereal demand in Sub-Saharan Africa was 33%, with Sudan, Gambia and Zambia reaching a high dependency level of more than 80%.

Biofuels development is argued to have positive benefits in ensuring household food security through increased incomes and the growing export markets for energy crops. There are however number of factors that are not explicitly accounted for in many of the partial-equilibrium frameworks that generate these conclusions. In some countries in Africa, concerns surrounding food security have resulted in governments actively cautioning the development of biofuels. In Tanzania for instance, as a result of mounting pressure from farmers and environmental groups, the government suspended all biofuel investments and halted land for biofuel development. In South Africa, maize was excluded from ethanol production amid food security concerns in the draft biofuel strategy.

Biofuel developments also present a potential competition between biomass systems for biofuels production and the use resources for animal feed, bedding, fertiliser and construction materials. Of particular concern are threats from business orientated production of biofuels that may require opening of forests or acquisition of land from rural dwellers for growing energy crops. Additionally, the market prices of energy crops may be greater than for food and induce the diversion of resources away from food to biofuel production; thereby threatening food security (AMIGUN, et al., 2011). However, all this implication was not proven in the case of Zambia as the case study focus was only targeting the poor resource farmers.

6.3.5 Diversion of extension services

Diversion of agriculture extension services from food to Jatropha. Jatropha is a new crop that needs to be understood further if it is to deliver benefits to the target beneficiaries and countries. It provides an opportunity to diversify land utilization and intensified agriculture extension. In all the projects, dedicated extension was required since the crop expansion was something new to the community. Little local knowledge was available on Jatropha and this meant that more close supervision was needed.

6.3.6 Diversion of markets

Diversion of markets when price of Jatropha is way above that of food crops. In a situation where Jatropha or any energy crops become lucrative, farmers may decide to divert land, investments and whatever they possibly can to earn that extra income.

This can cause serious food production reduction and maybe food price hikes. In Bio-ex, this was not the case as Jatropha price being offered was perceived by farmers to be lower than that of maize and other crops.

6.3.7 Diversion of fertiliser subsidies and funds

Diversification of subsidized fertiliser inputs to Jatropha might compete with crop production that can create price spike in future. Most governments in southern Africa have farming inputs (mainly seed and fertiliser) support programmes. Malawi and Zambia implemented Fertiliser Input Support Programme that gave an amount of fertilizer bags based on the ploughed area. In the event when biofuels crops guarantee high return in terms of income, farmers will likely divert some of the fertiliser input to energy crops. This may severely impact on the crop yields and may lead to low cereal stocks in the country. Diversion-based evaluation showed that out-grower schemes had higher risk of fertiliser diversion and therefore it is important to have policy interventions to avoid this.

6.3.8 Cultural heritage and sovereignty

Obliteration of cultural sites can not only be driven by wars, as discussed by (DITTMANN and ALMOHAMAD 2015), but by development as well. Agricultural expansion for energy or cash crops can cause encroachment on cultural heritage sites such as graves, riparian shrines (imishitu) and village ruins of significant value. Introduction of new food crops also may have implication on food sovereignty. Although the diversion-based framework did not amplify this risk, Jatropha farms in Kachumu and Rufunsa in Zambia may encroach in the sacred riparian forest along the nearby rivers.

Maize is a case in point that has diverted people in some parts of southern Africa from their traditional food to the horror of maize consumption. Before the LIMA programme in Zambia, the main staple food for people in Luapula and North-western provinces was cassava and sorghum. With time, maize has altered the taste buds of the young generation (like the author’s own children) and replaced it with an appetite for maize and its processed products. As a result, when people are asked whether they have food, they tend to answer NO is maize meal is absent. This is absurd and need to be looked at. Awareness campaigns need to start in Malawi and Zambia that “*FOOD* *is NOT only MAIZE"* and "Plants need WATER not RAIN" as strategies to reduce dependence on maize and increase irrigation agriculture respectively.

6.4 Concluding remarks

The quest to deliver on the rural development promises by southern African countries and reduce hunger and poverty while at the same time meeting both food and energy securities were some of the drivers of Jatropha development. Most of the projects were driven by foreign investors who had seen the opportunity of a lucrative biofuels market targeted at meeting the emission reductions targets especially for the European countries. Impact of expansion of developing Jatropha biofuels value chains are complex to understand. The diversion-based evaluation framework indicated that farmers in the SADC countries studied are or can be affected in a different way. The main diversions have been highlighted in this chapter and these can form a basis for designing and implementation of sustainable biofuel value chains.

7 Conclusion and recommendation: Biofuels and sustainability

Many policy measures and strategies have been designed and implemented to reduce the anthropogenic GHG[28] emissions into the atmosphere from fossil-fuel used in electricity generation, combustion engines and land use change**.** Biofuels have been considered as one of the options to transition from a fossil-fuel-depended transport sector to a much cleaner source as they are seen to have a positive net energy balance (NEB[29]). It is this that has caused so much global debate and attention on biofuels development in the recent past.

Among oil bearing crops, Jatropha was considered to possess the potential to meet the criteria of energy crops for biodiesel while sugarcane was considered as a viable option for bioethanol. It was considered "the miracle crop" at the time that could deliver on most promises of biofuels that included among other things (GLOBAL BIOENERGY PARTNERSHIP 2007; ACHTEN 2010). Several projects, driven mainly by foreign investors, were introduced and implemented in the region but (most if not all) failed to deliver on the promises and left many people desperate.

Most of these projects failed and the reasons for failure are many ranging from the absence of conducive policy and institutional frameworks to poor designed and execution. Evaluation of why the projects failed and in particular the impact they would have had on food security and sustainability confirmed a number of things: divert investment meant for food production to biofuels. This may negatively impact food production, the environment to some extend and food security. It may modernise and increase efficiency in agriculture. Clear policies and implementation guidelines are critical to avoid or minimise this effect.

[28] Green House Gases

[29] Net Energy Balance, relates energy input and output throughout crop production and conversion to biofuel

7.1 Remarks on aims, specific objectives and approach of study

The main aim of this work was to develop a conceptual evaluation framework and appropriate tools/methodology which can be used in evaluating potential diversions and impacts of Jatropha-based biofuels programmes at project, national and/or even sub continental-region levels.

The specific objectives of this study were to:

1. Empirically assess Jatropha as an energy crop in terms of its biophysical and agronomic demands including its carbon storage potential
2. Evaluate the bio-physical and agronomic conditions, potentials and constraints for biofuels development in SADC
3. Develop a conceptual evaluation framework for assessing biofuels diversions and its impacts on food production and sustainability
4. Conduct an evaluation of Jatropha projects using the framework to identify critical success/failure factors of selected case study projects in selected SADC countries
5. Document lessons and recommend key policy-based instruments and conditions for a sustainable biofuels programme based on the evaluation framework

The complexity of the potential and constraints of developing sustainable biofuel value chains in general and in the SADC region (in particular) demands a wide range of approaches ranging from empirical field trials to understand the choice of feedstock, analyse and evaluate biofuel value chains development against sustainability and implied impacts on food security. Therefore, a single method approach would be inadequate to comprehensively answer a multiple of convoluting questions. A mixed methods research design approach to inquiry that combines both qualitative and quantitative methods was therefore adopted to conduct this research.

7.2 Limitations of study and recommendations for further studies

The SADC region is a very diverse region both in terms of biophysical conditions and landscapes, economic aspects and the level of development and their governance. The influence of the colonial legacies is still active in the region, which makes research in such countries a sweet challenge. The region is endowed with an abundance of natural resources ranging from mineral reserves, arable land, rich biodiversity and good infrastructure compared to other regions. At the same time, it is the region that is predicted to get warmer and drier with severe consequences on agriculture, the main stay of many of its people.

In terms of biofuels development, SADC countries were at different stages at the time of this study. Different models were preferred and adopted which had completely different objectives ranging from rural development and income diversification, liquid fuel supply and energy security to climate related mitigations to a lesser extent. This in itself posed a major challenge in applying the DBEF consistently due to different emphasis in approaches.

The diversity and the absence of on-going projects and specific data posed a major challenging in defining the focus of the evaluation of Jatropha biofuel value chains. It affected the application of the method and the type of data that needed to be collected. A meta evaluation approach for example is limited in unearthing salient issues. As a result, this study falls short on the specifics such as the impact on the environment, the macro socio-economics of the region as well as localised impacts in many places where Jatropha was implemented.

Therefore, more targeted research is recommended to be done to assess conditions and potentials for energy crops before coming to some conclusion because the SADC region has potential to develop sustainable biofuels value chains. A look at technology, agronomy, socio-cultural landscape and overall sustainability issues and aligning these to SDGs would be a welcome move.

This study recommends that a hybrid and integrated sectoral approach to designing policies and programmes for biofuel value chains that puts local needs and context, triangulated with national or Africa sub-continental macro-economic needs aspects, is critical for sustainability than a neo-liberal top-down approach. The later tend to create dependencies that can cause disruption of food production systems, markets and possible irreparable damage to people's livelihoods and the environment in medium to long terms.

Despite the absence of thriving projects, biofuels are projected to remain an important energy development target in many countries in the SADC region even when depressed petroleum prices persist. The opportunity that dawned with biofuels, though missed, can still be harvested with enormous potential to lift our people from poverty and increase their resilience to global changes and shocks. The caveat is that other crops such as sweet sorghum, sugar cane, palm oil, cassava and even bamboo should be considered rather than Jatropha if biofuels have to redeem its reputation in the SADC region.

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Appendix B: Selected Diversion Results

	Land						Water		
	Rights	Size	Use	Lscore		Right	Qty	Quality	Wscore
BIO-EX	0	4	2	6	BIO-EX	1	2	0	3
D1-BP	5	5	5	15	D1-BP	3	2	1	6
KAPIRI	0	2	3	5	KAPIRI	1	2	0	3
KJGA	2	3	4	9	KJGA	2	2	1	5
SJO	0	3	3	6	SJO	1	3	0	4
LLD	5	5	5	15	LLD	1	2	2	5
BERL	1	5	4	10	BERL	1	2	0	3

		Input					Market		
	Labour	Fertilizer	Finance	Iscore		Local	National	International	Mscore
BIO-EX	4	3	2	9	BIO-EX	1	3	2	6
D1-BP	5	0	5	10	D1-BP	1	2	5	8
KAPIRI	4	4	3	11	KAPIRI	1	2	2	5
KJGA	5	0	5	10	KJGA	2	3	4	9
SJO	4	4	3	11	SJO	1	3	2	6
LLD	5	0	3	8	LLD	2	3	5	10
BERL	4	3	2	9	BERL	1	3	2	6

		Services			Project	Srisk
	Loans	Extension	Training	Sscore		
BIO-EX	2	4	5	11	BIO-EX	1.1
D1-BP	0	2	2	4	D1-BP	2.9
KAPIRI	3	3	3	9	KAPIRI	0.7
KJGA	0	3	4	7	KJGA	2.8
SJO	4	4	3	11	SJO	1.7
LLD	0	5	3	8	LLD	4.8
BERL	2	4	4	10	BERL	1.6

Key: Score scale: 0 to 5 | 0 = No diversion | 5 = Very High potential

Appendix B: Selected Photos

Photos taken by Author during the fieldwork in North-western Province, Zambia 2011