A Budget Analysis Of Different Soil Fertility Treatments For Conventional And Organic Vegetable Farming On A Smallholding In South Africa

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own original work, that I am the authorship owner thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: March 2018

Abstract

The threat of food insecurity due to overpopulation led to the development of green revolution (GR) technologies in the mid 1900's. The principles and technology became popular due to their efficiency and form key components of conventional agricultural practices. In the 21st century the same threats are faced predominantly due to overpopulation, resource limitation and growing middle classes of developing nations. This time around the technologies developed during the green revolution have been queried as a result of their negative side-effects on the environment, societies and economies. Thus organic agricultural principles have been proposed as an alternative to conventional agriculture to sustainably uphold food security at present.

Organic agricultural practices and philosophies aim toward a more systemic approach in farm management. The use of genetically modified organisms (GMO's) and synthetically produced agrochemicals is prohibited from use in organic production systems. The market for organic produce is growing globally; mostly in North America and Europe; African and South African markets in particular are growing less quickly. Due to the higher premiums earned from organic produce, as well as lower input costs it can potentially be a source of extra profit from smallholders.

The dossier of information and technological developments for organic agriculture are miniscule when compared to those for conventional agriculture. Developments for use in organic agriculture needs to be technically efficient and financially feasibility at production level. In this way the economic sustainability as part of overall sustainability can be evaluated. Through gross marginal analyses, this study made use of enterprise and partial budgets to compare the relative profitability of using organic fertilizers as opposed to using conventional fertilizer in a small scale vegetable production system near Raithby, Western Cape Province. The data source for the budgets was a technical field study which quantified the biophysical responses in broccoli and green beans to the respective organic and inorganic treatments applied to each crop. It was found that for both crops grown, the conventional approach had the highest and most positive gross margin when no premiums were present (ZAR 180 583 for green beans and ZAR 246 482 for broccoli). It was also found that the profitability of growing

broccoli organically could be improved by using 20% and 40% premium scenarios. The same observation was made for organically treated green beans. Adding premiums to the selling price of organic green beans for one of the treatments made it more profitable than farming the beans conventionally.

Opsomming:

Die gevaar van voedsel sekuriteit as gevolg van oorbevolking het gelei tot die groen revolusie tegnologie in die middel 1990's. Die beginsels en tegnologie wen gewildheid weens die doeltreffendheid daarvan en word sleutel komponente van konvensionele landbou praktyke. In die 21ste eeu word dieselfde gevare ervaar, hoofsaaklik weens oorbevolking, hulpbron beperktheid en die groeiende middelklas in ontwikkelende lande. Tans word die tegnologie wat tydens die groen revolusie ontwikkel is bevraagteken weens die negatiewe impak daarvan op die omgewing, gemeenskappe en ekonomieë. Daarom is organiese boerdery voorgestel as 'n alternatief vir konvensionele landbou om voedsel sekerheid volhoubaar te ondersteun.

Organiese landboupraktyke en filosofie mik na 'n meer sistemiese benadering tot boerdery bestuur. Die gebruik van geneties gemodifiseerde organismes en sinteties geproduseerde misstowwe is ontoelaatbaar in organiese produksie stelsels. Die mark vir organies geproduseerde voedsel groei globaal, maar meestal in Noord Amerika en Europa, Afrika en veral Suid Afrika se mark groei stadiger. Danksy die hoe premies ontvang op organies geproduseerde voedsel, asook die laer insetkoste, kan organies geproduseerde voedsel 'n winsgewende bron van produksie vir kleinboere wees.

Die inligtingsdossier en tegnologiese ontwikkeling van organies geproduseerde voedsel is gering, gemeet aan die van konvensionele landbou. Ontwikkeling vir gebruik in organiese produksie moet tegnies doeltreffend en finansieel haalbaar wees vir implementering op produksievlak. Op die manier kan die ekonomiese volhoubaarheid as deel van volhoubare landbou evalueer word. Deur middel van bruto marge ontleding is vertakkingsbegrotings en gedeeltelike begrotings aangewend om die relatiewe winsgewendheid van organiese bemesting teenoor konvensionele misstowwe op kleinskaalse boerdery naby Raithby, in die Wes-Kaap Provinsie. Die bron van data vir die begrotings is tegniese proewe wat die biofisiese reaksies van broccoli en groenbone ten opsigte van verskille bemesting behandelings.

Vir beide gewasse het die konvensionele bemestingsbenadering die hoogste bruto marge gelewer waar geen premie aanvaar is vir organies produseerde groente (R 180 583 vir groen bone en R 246 482 vir broccoli). Die winsgewendheid van broccoli word

bevoordeel met premies van 20% en 40% onderskeidelik. Dieselfde geld vir groenbone. Die premie op groenbone wys ook hoër bruto-marge as vir konvensioneel geproduseerde bone.

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Table of Contents

List of Figures

List of Tables

List of Annexures

List of Abbreviations

CIMMYT- International Maize and Wheat Improvement Centre

DAFF – Department of Agriculture Forestry and Fisheries

DDT- Dichlorodiphenyltrichloroethane

GHG – Greenhouse gasses

GM- Gross Margin

GMO – Genetically Modified Organism

GR-Green Revolution

GVP- Gross Value of Production

IOL- Independent Online

K- Potassium

MRL- Maximum Residue Limit

MV- modern high-yielding varieties

OPV- Open Pollinated Varieties

N- Nitrogen

NAMC- National Agricultural Marketing Council

NPK- Nitrogen Phosphorus Potassium fertilizer

PAN- Pesticide Action Network

PBA- Partial Budget Analysis

R- South African Rand

Rs.- Rupees

TVA- Tennessee Valley Authority

UN DESA- United Nations, Department of Economic and Social Affairs

USDA – United States Department of Agriculture

USA – United States of America

WHO- World Health Organisation

WTO- World Trade Organization

WWI- World War I

WWII- World War II

ZAR- South African Rand

ha – Hectare

t/ha – tons per hectare

Chapter 1 : Introduction

1.1. Background

Over recent years, reports of increased greenhouse gas (GHG) emissions due to farming of livestock have dubbed this (i.e. GHG emissions) as one of the main instigators of increasing planetary temperatures. According to Tubiello et al. (2014), enteric fermentation was held liable for 40% of the world's total greenhouse gas emissions caused by agriculture in the year 2011. The same authors mentioned that, from the year 2001 to 2011, cattle (dairy and non-dairy) were accountable for 74% of total global enteric greenhouse gas emissions. The land and resource requirements of livestock husbandry compete with the interests of the crop production industry as animals, like the plants they eat, also need fresh water as well as land; either for grazing or (and) for cultivating the animal feed. Furthermore, there is an increasing tendency of the middle class in developing countries to supplement their diets with meat as they earn more money (Delagado, 2003). Delagado (2003) estimated that the middle class of all developing countries would consume 63% of all meat produced in the world by 2020. This would augment the already existing pressures on arable land and fresh water resources created by the demand for agricultural products (Olesen & Bindi, 2002; Kirchmann & Thorvaldsson, 2000). Hence the proportion of land reserved for crop production must be used in such a way that it is not exploited, whilst simultaneously optimizing the yield.

Higher demand of animal products by consumers is not the only phenomenon hindering the crop production industry's expansion. Climate change is affecting crop production systems globally (Olesen & Bindi, 2002). The affects differ according to current climatic conditions (regionally and globally) and vary in influence depending on the accessibility of infrastructure to manage any change (Olesen & Bindi, 2002).

It is important to acknowledge that the crop production industry is also at fault when it comes to preservation of the environment and sustaining socio-economic equilibria. For example; vast deforestation in Indonesia to establish palm-oil, sugar and soya plantations (influenced by consumption trends) (Tan et al., 2009); chemical use in crop production and the negative effects it has on humans; over-use of fertilizers and irrigation water. Economically the price of inputs such as fertilizer tends to increase (DAFF, 2015a). Evidently a restructuring of crop cultivation techniques, which requires the farmer to be less dependent on inputs, is essential.

As the world's human population grows, the demand for food increases as well. Alexandratos and Bruinsma (2012), reported that in 2007 the average person in the world ate 2772kcal (11600kj) worth of food per day. The aforementioned value was expected to increase to 2860kcal (12000kj) by the year 2015. Increasing levels of food consumption further pressurizes farmers to meet these high demands in a shorter period of time, whilst simultaneously minimizing damages made to the natural environment during production. This means that efficient use of land and production of food is important for the progression of modern agriculture.

One of the novel innovations within agriculture aiming to improve the efficiency of input use and production is precision agriculture. Precision agriculture involves the utilization of geospatial sensory techniques such as GPS and remote sensing, to detect skewness in crop performance in the field (Zhang & Kovacs, 2012). Application of such technologies allows farmers to be more judicious and accurate with farm inputs such as water, fertilizers and herbicides. According to Zhang & Kovacs (2012), studying these field variations entails the use of high-resolution satellite imagery which is relatively expensive and applying them in precision agriculture therefore becomes financially impractical. The same authors proposed the use of the cheaper low altitude remote sensing platforms, or small unmanned aerial systems. However companies offering such services tend to have a minimum area threshold for capturing aerial photographs. This means that a small scale farmer interested in applying the aforementioned technology might have to purchase spatial imaging for land that falls out of his or her property's boundary. It is apparent that scientific research is needed to cater for the financial restrictions of small scale farmers.

In many developing countries, small scale farmers contribute largely to the economy especially through crop production (Godfray et al., 2010). According to Pienaar and Traub (2015),13% of agricultural land in South Africa is occupied by 4 million small scale farmers (mostly black). The remaining 87% of agricultural land is occupied by 39 982 commercial farmers who produce 95% of the nations agricultural goods (Aliber

& Hart, 2009). Pienaar and Traub (2015) estimated that 35 000 of the latter farmers were white. There are also more jobs created per unit of investment in agriculture than in other sectors. The implication therefore, is that growth in agricultural output is prolific for job creation (Department of Agriculture Forestry and Fisheries (DAFF), 2007). This is noteworthy given that the unemployment rate amongst blacks in South African is the highest whilst that for whites is the lowest (Klasen & Woolard, 2009).

The discourse surrounding organic and sustainable agriculture is relatively undeveloped when compared to the convention. Harwood (1990) mentioned that sustainable agriculture was first introduced as regenerative agriculture in the early 1980's. The use of the term 'sustainable' only increased in frequency from 1987, when referring to agricultural systems that interlink agriculture with ecology and society on a global level (Harwood, 1990). In a world where conventional agriculture has been perpetuated throughout the last century, it is no surprise that modern literature relating to sustainable agriculture is comparatively less than the dossier for conventional agriculture. The lack of quantitative information regarding sustainable agriculture (particularly in small scale crop production (Godfray et al., 2010)) therefore makes it difficult to analyse alternative strategies and lobby for policies that support the sustainable agriculture movement (Godfray et al., 2010). Furthermore, innovations need to be tested for socio-economic relevance. Applying novel developments within agriculture at the farm level should make economic and environmental sense to the adopters.

Only 13% (15.8 million ha) of South Africa's surface area is arable enough to support crop production (DAFF, 2007). However, even some of the soils that are suitable for crop production still require nutritional inputs to help diminish the gap between possible yields and actual yields (the yield gap). Compost, together with biochar, and other organic fertilizers have been suggested as alternatives to the traditional industrial mineral fertilizers (Agegnehu et al., 2016; Fischer & Glaser, 2012). Although the scientific costs and benefits of organic fertilizers have been widely tested, less effort has been made to evaluate the economic impact of organic fertilizers included in a crop production system (Dickinson et al., 2015). Considering that organic vegetable production (if higher prices are obatined) could support small-holder producers it is important to invetigate the potential profitability of such farming systems.

1.2. Problem statement and research question

Globally, organically produced crops (for fresh consumption and processing), are gaining popularity amongst agriculturalists. The driving forces behind the increase in demand for organic products are still somewhat unknown. The cost of organic production often exceeds that of conventional methods. Organic items, irrespective of comparative costs of production, are often more expensive than the same items produced conventionally. The possibilities to produce and price organic products at rates that compete with the volumes and lower prices of conventional crops are uncertain. These are the same key issues and questions with regards to organic food production methods.

As previously mentioned, there is comparatively less quantitative research-based information available on organic agriculture, than for conventional agriculture. Scientific research focusing on organic or sustainable fertilizing methods needs to include an economic perspective in order to measure the real cost of using organic fertilizer. To determine the financially viability of using the theorized organic fertilizer is important. The problem is a lack of understanding of the financial implications of organic production methods, specifically related to vegetable production in Stellenbosch within the Western Cape Province. The key research question is how do various organic fertilizer incorporation strategies financially compare to industrial fertilizers?

1.3. Objectives of study

The main aim of this research is to assess the implications of using various fertilizer options in vegetable production systems within the Stellenbosch area. In support of this aim the following goals are set: (i) to assess and describe the technical differences between the systems of organic and inorganic fertilizers, (ii) to identify farming strategies incorporating organic fertilizers and (iii) to financially assess each strategy comparatively.

1.4. Methods

This project (Phase II) depends on the results generated by another project (Phase I). Phase I is carried out by Sikho Gobozi. Both phases of the project are carried out concurrently.

The proposed study is carried out on a small-holding farm located near Raithby, a dwelling approximately 15 km south of Stellenbosch. Two different vegetable crops grown in different seasons are included the trial. The small-holder farmer (Aron Mabunda) together with the researchers from Stellenbosch University (Philemon Sithole and Sikho Gobozi) is responsible for managing the field trial.

For the purpose of analysing the expected financial implications of replacing the existing fertilizers with the fertilizers used in the treatments a representation of the reality of a farm was constructed. For this purpose simulation modelling was utilised. Farm system simulations have the potential to describe a farm system financially (Hoffmann, 2010). They also have the potential to allow for a sensitivity analysis of adjustments made to parameters in the enterprise model (Hoffmann, 2010). Enterprise budget models have been developed to fulfil this purpose via a system of interrelated mathematical and accounting equations. Such models determine the sensitivity of variables by quantifying their effect on enterprise level profitability (Hoffmann, 2010).

For the purpose of this project a combination of enterprise budgets and partial budgets were constructed. Both these techniques allow for capturing of scientific data, which is in this case a necessity. Both techniques are designed to organise technical data and parameters into a standard accounting format that is also comparable to other enterprises and industries. The main benefit of these techniques is the fact that they are commonly used in research and are well known by farmers (Knott, 2015; Hoffmann, 2010). This allows for access to and by producers and contributes to the user friendly nature that communicates well across disciplines, an important contributor in a field such as sustainability which is by definition multidisciplinary. Using these budgets gross marginal analyses were be performed to measure the financial performances of the treatments. Various adjustments to input values were used as scenarios in the form of price premiums, wage increases, fertilizer and organic certification costs to determine the comparative effects on the gross margins.

1.5. Outline of Study and thesis

Chapter 2 consists of a literature review that provides information around the mechanics of the transition from conventional agriculture to organic agriculture that is taking place. It also aims to substantiate the fundamental differences between conventional and organic agriculture. Furthermore, the literature review aims to objectively define the concept of sustainability and its relevance to the future of agriculture.

Chapter 3 provides background information on how modelling and budgeting of farm systems is done. The aim of this chapter is to assist the reader with conceptualizing budget modelling for farming systems.

Chapter 4 also provides a detailed description of the assumptions made, as well as the different scenarios that will be run. Details of the methods that will be used to construct the budgets in the context of this research are also provided.

Chapter 5 presents the budget models for each fertilizer treatment. The results from the different scenarios that were laid out in Chapter 4 and tested will also be reported in Chapter 5.

Chapter 6 provides a conclusion and summary regarding findings of this study. Furthermore recommendations will be made regarding the practical utilization of the models for the farmers benefit, and also where the design of such projects can be improved.

Chapter 2 : Organic farming as a component of sustainable agriculture

2.1. Introduction

Agriculture and the cultivation of land is an age-old practice that has been and is still part of societies. Snir et al. (2015) explained how the initial cultivation of land can date back as far as 23000 years from 2015, as opposed to the intial proposotion of 12000 years. However the way in which food is acquired by humans has since changed; from relying soley hunting and gathering, to the land cultivation methods applied in the modern era.

The conventions witnessed in modern agriculture have assisted in narrowing the yield gap. Technical applications to breeding, fertilizers and biocides helped to improve crop yields on farms (Fishcer & Edmeades, 2010; Lumus et al., 2008; Tan et al., 2007; Harker et al., 2003). However, there has been criticism of conventional agricultural practices due to the repercussions they have had, particularly on the environment (Gomiero et al., 2011). Pollution caused by agrochemicals as well as erosion due to intensive cultivation are two examples (Gomiero et al., 2011; Lal, 2010; Hillel, 2004).

Organic agriculture is a concept of agricultural production that is perhaps the opposite of conventional agriculture. It is promoted by several professionals in the field and other disciplines as being more sustainable in comparison to its conventional counterpart. There is also strong and open opposition to the idea of organic farming.

The literature review discusses the origin of conventional agriculture and its persistence into the 21st century. This section also discusses several catalysts behind the widespread adoption of conventional agricultural practices. Furthermore the shortfalls of conventional agriculture will be described and discussed with reference to the concept of sustainability. In the later stages of this chapter organic agriculture will be objectively defined and discussed. In this way both concepts of organic and conventional agriculture will be weighed up against each other in terms of sustainability.

2.2. Origins of conventional agriculture

Defining conventional agriculture is not an easy task as agriculture in the broad sense is constantly shifting and evolving to include (or exclude) different and novel agricultural practices. The definition also needs to evolve concurrently. The complexity of agricultural systems makes it difficult to assign a specific definition toward them. It is more convenient in this context to rather make reference to the characteristics of conventional agricultural systems in practice. According to Schaller (1993) conventional agriculture is characterised as being highly specialized, industrialized (intensive with the use aid of technologies), capital intensive (a relatively larger amount money needs to be invested on inputs) and reliant on synthetic off-farm inputs (i.e. inorganic chemical fertilizers and biocides). Conventional agricultural systems have placed primary emphases on achieving short term economic targets such as maximizing production by minimizing relative production costs (Allen et al., 1991). This means that limited attention is given for the environmental consequences of farming operations.

The countries of the west are and have been influential in the way conventional agriculture was perpetuated across the African continent and the rest of the world; from the 1900s right into the 21st century. According to Harwood (1990) agricultural industrialization in the USA was said to be rudimentary, but becoming more common at the turn of the 20th century. Farm numbers and sizes were accentuating until the peak number (at that time) of farms was reached in 1930 at 6.8 million. This surge welcomed a rise in farm mechanisation, input costs, and competition. Likewise crop hybrid development and acquisition were both proliferating.

The novelty of industrializing agriculture was not a streamlined process particularly at industrialization’s infancy. Innovation’s acute deviations from what was perceived as agricultural norms back then, conflicted with the ‘urban agrarian’ lifestyles of the people (Harwood, 1990). Therefore divisions between farmers were perpetuated as some farmers welcomed the new way, whilst others rejected conventional agriculture (Harwood, 1990).

Coupled with the surge in mechanization and industrialization, there was also a rise in the use of chemicals in the form of pesticides and inorganic fertilizer after the World

Wars. The development and improvement of transport networks and systems throughout history has improved the overall accessibility to various agriculturally related markets. This means that local producers are now able to promptly import machinery, equipment or agro-chemicals that are manufactured in foreign countries. Likewise, consumers are able to purchase food products out of their local growing seasons due to imports.

Having described briefly what some of the characteristics of conventional agriculture entails, it is important that the main drivers behind the adoption of conventional agricultural practices be highlighted and analysed. In this research, it is suggested that these drivers include population growth, scientific development and global politics. The following sections look into these drivers and how they have been instrumental in the widespread adoption of modern conventional agricultural practices.

2.2.1. Human Population and social dynamics

It is well documented that the world's human population proliferated substantially during the 1900s (United Nations, Department of Economic and Social Affairs (UN DESA), 2015; Lee, 2011; Hirschman, 2005; Lutz et al., 2004). Life expectancy before the 1900s was relatively low due to many brutal wars, famines and epidemics such as Bubonic plague in the 1400s (Gelbard et al., 1999). In the year 1900, the world population was approximately 1.650 billion (Gelbard et al., 1999). This means that it took roughly 250 000 years for the estimated world population to reach 1.650 billion from the initially proposed date of appearance of modern human beings (Stringer, 2002).

The century of the 1800s however was pivotal particularly regarding the European countries. Hygiene and public sanitation accentuated whilst malnutrition declined, thus lowering the incidence of human diseases (Parker, 2017). This was possible due to the significant developments in the understanding of vaccines, epidemiology and microbiology by scientists such as Louis Pasteur and Robert Koch (Berche, 2012). These factors, among others, resulted in a steady and faster rise in the population. At the turn of the 19th century (i.e. the year 1800), the world population was estimated to be 0.978 billion; a figure which is 0.672billion less than the previously mentioned population for the year 1900 (Gelbard et al., 1999). Furthermore two centuries prior to 1900, 0.610 billion was the estimated world population for the year 1700 (McEvedy & Jones, 1978). Evidently the 19th century was a period where world population growth amounted to a figure larger than the total estimated population at the year of 1700. This kind of population growth continued throughout the 20th century and has carried on in the 21st century due to increased developments and availability in technology, food and medicine.

According to the United Nations Department of Economic and Social Affairs (UN DESA) (2015), the world population in the year 2015 was 7.4 Billion. The world population has grown by more than fourfold over the last 115 years. Most of the aforementioned population growth occurred in the last 50 years of the 20st century (UN DESA, 2015). This time period corresponds with the post- World War II (WWII) era, Cold War, Space Race, and GR. This period welcomed significant advancements in modern science and technology and thus laid the foundations for life experienced by many of the western civilizations of the 21st century. Continentally speaking, the rate of population change has been and is projected to remain highest in Africa compared to the rest of the world (UN DESA, 2015). This phenomenon possesses significance since much of the world's remaining fertile soils are in Africa, whereas the highest levels of consumption reside in the other 5 continents. Regarding the regional population growth forecast from 2000 to 2100, growth is expected to plateau because the world's carrying capacity is finite (UN DESA, 2015). This carrying capacity of the planet includes the amount of natural resources the planet can provide per individual.

2.2.2. Green Revolution and technology development

It was mentioned by Fitzgerald-Moore and Parai (1996) that the post-WWII era was characterized by world-wide deficit in food; to which the GR was the response and proposed solution. According to Evenson and Gollin (2003) the term 'green revolution' was used due to the successful performance of transgenic modern, high yielding crop varieties (MV's) in the 1960's. High yielding varieties of wheat and rice were developed during the 1950's by developed countries, for use in developing countries located in Asia and South America (Evenson & Gollin, 2003). Both of these MV's were specifically bred to direct all photo-chemical and chemical energy into producing more grain. This was achieved at the expense of the MV's vegetative growth and resulted in individual plants with characteristically shorter and stiffer stems (Evenson & Gollin, 2003). What this meant was that land could be utilized more judiciously and efficiently, whist obtaining higher yields per surface area. This also meant that the crops could reach maturity much quicker than they could before. Modern crop varieties have also been developed to tolerate, herbicides such as glyphosate, to assist with the chemical management of weeds (Wright et al., 2010; Owen & Zelaya, 2005). This was achieved through the development of the first GMOs which officially commercialized in 1996 (Brookes & Barfoot, 2005).

Along with these genetic and biochemical developments, the GR also stimulated growth in the chemical industry. Agrochemicals developed and used during the GR helped to further close the yield gap (van Keulen, 2006). For example, insecticides where DDT was the active ingredient, killed a broad range of insects, thus providing a silver bullet for pest management in crop production practices (van Keulen, 2006). In addition, DDT takes relatively longer to breakdown thus its extended activation period meant that multiple applications were not necessary.

The emergence of synthetic, inorganic fertilizer was linked to the industrialization of insecticides. The potassium (K) industry in America was established during WWI and expanded following the discovery of K reserves in New Mexico and Saskatchewan in 1931 and 1958 respectively (Russel & Williams, 1977). The year 1903 saw the first synthetically produced nitrogen (N) fertilizers in the form of calcium nitrate. Low quality synthetic ammonia based fertilizers became accessible shortly after, in 1913. Improvements to the fertilizer quality were achieved concurrently with the formation of the Tennessee Valley Authority (TVA) in 1933 (Russel & Williams, 1977). Throughout the green revolution, nitrogen, potassium and phosphate based fertilizers were (and still are) fundamental in achieving the crop yields observed through conventional agriculture.

The modern plough such as the mouldboard, which rotates the soil and was developed in the 18th century differed significantly from its' original morphology which did not mix or invert the soil and was constructed out of plant materials (Derpesch, 2004). The mouldboard plough and its ability to control aggressive quackgrass (*Agropyron* *repens*) is considered as being the reason why famine and death was avoided across Europe at the end of the 18^{th} century (Derpesch, 2004).

From the abovementioned case it is clear that the plough was modified over the years to improve plough efficiency. Furthermore the tractor has been developed to electronically include functions that simplify ploughing, as well as other functions such as seed sowing and agro-chemical applications (Stone et al., 2008). Therefore the tractor has become an integral part of automation in conventional crop production.

2.2.3. Global and local policies

During the twentieth and twenty first centuries, governments both locally and internationally have influenced and implemented policies which supported conventional agricultural practices. According to Morris et al. (2007), the national fertilizer programs that were implemented by the respective African governments during the 1970’s and early 1980’s took the form of large and direct government expenditures. These implementations aimed at ensuring that both demand for and supply of fertilizers was augmented. Typically these government interventions came in the form of; direct subsidies which lowered the prices of fertilizer charged to farmers, input credit programs, and centralization regarding fertilizer procurement and distribution (Druilhe & Barreiro-Hurlé, 2012 ; Morris et al., 2007).

Generally, the aforementioned approach did not succeed in promoting a sustained increase in fertilizer use. This was because the costs (on the governments’ side) were often too high, governments were under-capacitated, and the policies were too rigid thus failing to acknowledge the diversity of production systems (Morris et al., 2007). Later on, donors together with the World Bank were in favour for the abolition of centralization and government subsidies (Druilhe & Barreiro-Hurlé, 2012; Minot, 2009; Morris et al., 2007; Heisey & Mwangi, 1996). The privatization of fertilizer companies also had the repercussion of pricier fertilizers (Denning et al., 2009).

From the year 2002, food, fertilizer and fuel prices on the international markets have increased (Ariga et al., 2008; Mitchell, 2008). The cost of manufacturing urea fertilizers, a process highly dependent on natural gas combustion, also accentuated due to the rise in gas prices (Morris et al., 2007). As direct government regulation of fertilizer markets through price controls or state owned-distribution systems proved unsustainable, more indirect forms of regulation were introduced. These indirect measures include the establishment of rules or policies, as well as incentives to monitor private action and stimulate investment (Morris et al., 2007).

Indeed there have been cases where direct input subsidies by government have succeeded. For example, Kenya, Zimbabwe and Zambia experienced substantial increases in maize productivity during the 1980’s (Denning et al., 2009; Eicher et al., 2006; Eicher & Byerlee, 1997; Blackie, 1990; Rohrbach, 1989). In Zimbabawe, purchases of fertilizer by smallholders between 1980 and 1985 grew by 45% and hybrid seed sales grew twofold (Rohrbach, 1989). In 1978 the Zimbabwean government initiated a credit scheme for smallholders who typically lacked access to credit before independence in 1980. Credit for the purchase of input packages (i.e. seeds, fertilizers and biocides) became available to smallholders through the Agricultural Financial Corporation (AFC) (Rohrbach, 1989). As a result the average smallholder maize yields during 1980s were more than double that of the 1970s (Rohrbach, 1989).

Similarly, Malawi managed to double and triple their maize production in the years 2006 and 2007 respectively, following the implementation of a national input subsidy and improved rainfall conditions (Denning et al., 2009). 76% of Malawian farmers opted to use their coupons (provided by the Malawi subsidy program) to buy hybrid maize seeds as opposed to the option of improved open pollinated varieties (OPVs) (Denning et al., 2009). However, hybrid seeds tend to be more expensive than improved OPV’s. Although there is a high preference amongst Malawian farmers for the former, small-scale farmers in climatically limiting regions often fail to recover the input cost of seeds and fertilizer in the absence of subsidies.

In other developing regions, the Asian GR (which started in the 1960s) managed to more than double cereal production on the continent between 1970 and 1995, from 313 to 650 million tons per year (Hazell, 2009). This was possible due to public spending by Asian governments. Intervention by governments in agricultural development improved farmers’ access to fertilizers, rural credit, technology, information and extension services (Hazell, 2009; Djurfeldt & Jirström, 2005). In India, state investment into agriculture infrastructure (e.g. irrigation) within a region prompted farmers in the same area to invest in high yielding seed varieties as well as fertilizers (Sebby, 2010).

Countries who wanted to implement GR technologies needed to import them from foreign states if they lacked the resources locally. Therefore trade barriers needed to be limited. Initially, General Agreement on Tariffs and Trade (GATT) was established post-WWII in 1947 to serve as a medium for the negotiation of reduced trade tariffs and barriers between different countries (World Trade Organization, 2014). GATT was renamed as the World Trade Organization (WTO) when it was established in 1995 and is similarly geared toward negotiating for the removal of international trade barriers. These organizations have helped to improve relations between countries and thus their import and export agreements; hence streamlining the process of international trade. The WTO's Committee on Agriculture specifically aims to ensure the correct implementation of WTO agreements and rules within agriculture amongst its member states (WTO, 2014). Thus the WTO has had a hand in the implementation globalization policies which have aided the international exchange of agriculturally related goods and services.

A graph by Morris et al. (2007) illustrates the trend in NPK fertilizer imports from the year 1962 to 2002. Although there were periodic fluctuations in imports, the trend over the entire period shows that there was an overall increase. The years from 1962 to 1985 welcomed a steady growth in fertilizer imports. This growth however stagnated between the years 1985 and 1995. The period between 1995 and 2002 however welcomed a sharp accentuation in the fertilizer imports. This spike in imports coincides with establishment year of the WTO (1995) as well as the early post-apartheid era.
The cases mentioned previously regarding the Asian GR and African agricultural development illustrate the necessity of government expenditure (direct or indirect) to promote, invigorate and sustain the agricultural activity. Policies implemented both locally and globally facilitated the introduction of conventional agricultural innovations into the mainstream. The threat on food security in the 1900s by population growth meant that without the GR other possibilities of addressing food deficits would have had to have been explored.

2.3. Sustainable agriculture

When considering the sustainability of an agricultural system, one needs to specify and define the perspective from which the agricultural system is viewed. According to Allen et al. (1991a), there are two prevalent themes used to define sustainability in agriculture; the first theme places an emphasis on resource conservation and profitability, whilst the second theme focusses on defining sustainability in terms of social problems that woe the industry. Other authors, more recently, have split the first theme to conceptualize sustainable agriculture under a total of three themes; social acceptability, economic viability, and environmental soundness (Rasul & Thapa, 2004 and Yunlong & Smith, 1994). Historically, an overemphasis has been placed on defining agricultural sustainability in terms of the technical issues; conservation of natural resources and profitability. In addition ignoring the social aspects can cause one to miss the root sources of unsustainability of agriculture (Allen et al., 1991b). Hence a broader definition of sustainable agriculture needs to place equal importance on both the technical and social aspects of the respective agricultural systems. Hence the proposed definition of sustainable agriculture which was also provided by Allen et al., (1991b:37) and that will be used throughout the rest of the thesis is as follows:

"A sustainable food and agriculture system is one which is environmentally sound, economically viable, socially responsible, non-exploitative, and which serves as the foundation for future generations."

Indicators are used to evaluate the three components of sustainability but the difficulty in measuring sustainability lies within the fact that it is complex, dynamic and often site-specific (Hayati et al., 2010). Precisely measuring and defining sustainability in agriculture is dependent on the analysts' perspectives' (Webster 1999). This means that different stakeholders in systems can have conflicting conclusions regarding the sustainability of the system.

2.4. Problems with conventional agriculture

The shortcomings of conventional agricultural practices are typically classified as being social, economic or (and) environmental; the three spheres used for evaluating sustainability (Hansmann et al., 2012). Hence, what follows below is a review of the side effects of conventional agricultural practices in the context of the three aforementioned pillars of sustainability. However, it must be mentioned that the social, environmental and economic spheres of sustainable agriculture are frequently interdependent (Hayati et al., 2010).

2.4.1. Social

In developing countries such as India, government implemented extension services regarding the use of conventional inputs such as genetically modified seeds and pesticides were not well established; which left the private companies who sold the inputs to the farmers responsible for any technical consultations (Guere & Sengupta, 2011). Farmers in India who typically were not privy to the information regarding use of pesticides and hybrid seed varieties such as Bt cotton were susceptible to exploitation by the salesmen (Guere & Sengupta, 2011). Authentic Bt cotton seeds were expensive hence there were cases of spurious Bt cotton seeds being sold at a lower price to lure farmers who opted to save money on seed costs (Herring, 2008). Like Bt cotton the cost of the corresponding pesticides were also highly priced and it was found that some farmers in the states of Gujarat and Maharashtra, were convinced to spray pesticides at higher rates than the optimum (Shetty, 2004). Therefore the input costs that farmers incurred had increased due the exaggerated use of costly pesticides on Bt cotton seeds that were not always authentic. Farmers who were not breaking even had to take loans to cover the input costs and the overuse of pesticides caused resistance to build up in pests such as bollworm which ultimately lowered the yields (Guere & Sengupta, 2011). The change in climate and hence lack of guarantee of a harvest has accentuated this even further as most farmers in Maharashtra practice rain-fed cultivation (Guere & Sengupta, 2011). As a result several famers defaulted on their loans thus rendering them bankrupt and farmer indebtedness has been one of the main causes of farmer suicides in India (Guere & Sengupta, 2011; Mishra, 2006).

The point in the abovementioned case is that farmers who are uninformed can lose their business sovereignty and risk becoming dependent on agricultural products manufactured and sold by private firms. The sophisticated understanding behind some conventional agricultural technologies constantly needs to be transferred and translated to the farmer by an objective intermediary. Failure to transfer this knowledge about conventional technologies, as seen in the previous case, can lead to significant losses, as also seen with the development of resistance in bollworm (Guere & Sengupta, 2011). Farmers who need to buy inputs from private companies in the absence of government assistance can be vulnerable to price inflation.

Britain and other European colonial powers historically depended on the exploitation of cheap labour in their colonies for agricultural production (Walvin, 2007). In post-colonial South Africa, the agricultural industry pays the lowest wage to labourers per day when compared to other industries. According to the White Paper (Republic of South Africa, 2016) on basic conditions of employment act, no.7 75 of 1997, the minimum wage for farm labourers between 1 March 2016 and 28 February 2017 was ZAR 14.25 per hour; approximately ZAR 2778.83 per month. The performance of the median farm worker minimum wage relative to that of other sectors in 2014 can be observed in Figure 2.1. The graph taken from Cottle (2015) shows that only domestic workers (ZAR 1631), public works programs employees (ZAR 1819) and taxi drivers (ZAR 2274) were paid less than farm workers.

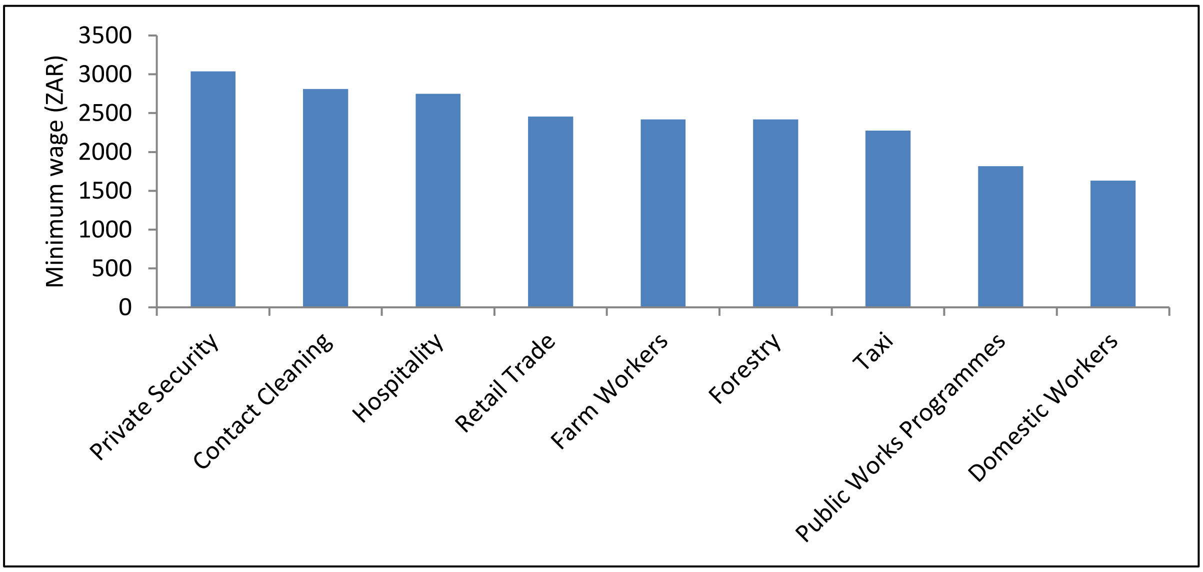


Figure 2.1: Minimum Median Wage for Sectoral Determinations 2014 in ZAR: Source: Cottle, 2015.

South African farm workers are mostly black and unskilled and as a result are most likely to lose their jobs (Munakamwe & Jinnah, 2014; Simbi & Aliber, 2000). Munakamwe and Jinnah (2014) reported a 5.1% drop in total commercial farm jobs between 2010 and 2014, from 866 455 employees to 709 000, thus adding to competition for unskilled farm jobs. In order to avoid any disputes with labourers, farmers are becoming more inclined to use mechanistic innovations more frequently to replace the farm labourer. In many cases the option is usually cheaper. Consequently African immigrants tend accept payments lower than minimum wage; either out of ignorance or lack of alternative options (Munakamwe & Jinnah, 2014).

Many of the chemicals used in conventional agricultural practices are directly toxic to the health of humans. It was estimated by the World Health Organization (WHO) that acute pesticide poisoning (APP) affects 3 million people globally, of whom 20 000 become fatalities (Dabady & Tulk, 2015). Developing countries harboured 99% of the 20 000 fatalities caused by pesticides (Dabady & Tulk, 2015). Typically the people most vulnerable to the toxicity of these chemicals are the people who handle them directly and incorrectly. This is common in developing countries where the transfer of information and knowledge regarding the safe-use of such chemicals is often inadequate (Kishi, 2002). According to Kishi (2002) the groups of chemicals that are the major culprits of APP are cholinesterase-inhibiting pesticides (i.e. organophosphates and carbamates). Symptoms of intoxication include vomitting, muscle fasciculation and diarrhoea. Likewise in Costa Rica foetal paraquat poisoning has reportedly caused liver impairment followed by pulmonary edema, whereas endosulfan has been reported to cause death and permanent neurological impairment in the USA (Kishi, 2002).

It is important to recognise that agro-chemicals play a significant role in the global economy. In 2007, 2.36 billion kilograms of pesticides were used globally, which generated business valued at 40 million USD; in the year 1950 the amount of pesticides used was 50 times less (Dabady & Tulk, 2015). According to IBISWorld (2016) the total global revenue generated by all agro-chemical (i.e. pesticides, fertilizers etc.) manufacturers amounted to 157 billion USD. This figure was generated by approximately 7156 businesses that employed 557 000 people worldwide. What is also important to note is the number of people and businesses worldwide relying directly on the manufacturing of agrochemicals as a source of income. Addressing the environmental and socio-economic issues directly involving agrochemicals is therefore complex. The amount of trade-offs and stakeholders dependent on merely the manufacturing of agrochemicals should be taken into consideration.

Many countries involved in the international trade of agricultural products have responded to the food safety threat posed by some of the agro-chemicals by passing regulations. According to the World Health Organization (2008), Maximum residue limits (MRL) for pesticide use are set as the upper thresholds for the maximum number of agrochemicals that are legally permitted in the production process of fresh produce. South Africa follows its own set of MRLs whereas most other African states implement the Codex Alimentarius MRLs (Spanoghe, 2017). In the EU the European Commission sets the MRLs. MRLs that have been set by the respective nations are aimed at protecting the health of the consumer (Spanoghe, 2017). Manufacturers of agrochemicals therefore need to compete more with one another in order to gain market share, given the restrictions placed on producers.

2.4.2. Environmental

Approximately 75 billion tons of soil is eroded on an annual basis, with agricultural production systems being the main contributor causing 20 million tons of topsoil erosion per annum (Ananda & Herath, 2003). Loss of soil organic matter and erosion are exacerbated by intensive farming which results in a diminished resilience to extreme changes in climate (droughts and heavy rainfall) (Gomiero et al., 2011). In the 1930s, a wind erosion event known as the Dust Bowl occurred in the USA's Southern Great Plains (Hillel, 2004). The phenomenon was due to a combination of events, namely the mass adoption and use of mechanical land cultivation in the region, as well the vast area's aridity at the time (Lee & Gill, 2015; Libecap & Hansen, 2002). Due to low rainfall in 1934, the loose and dry soil was blown into suspension by the wind, which created red fogs of dust large and consistent enough to block the sunlight and choke both people and animals. Other regions of the continent including Canada were also affected by the finer dust particles that had migrated en mass (Lee & Gill, 2015).

The topsoil is the most biologically active region throughout the soil profile and typically is the most fertile. Thus loss in depth of topsoil also reduces the agricultural productive potential of land (Thompson et al., 1991). Soil organic matter improves the nutrient and water retention capacity of the soil and improves the water use efficiency of crops (Gomiero et al., 2011). Sustainable agricultural systems such as conservation agriculture have been a response taken up by some producers to address the issue of soil erosion. A few of these practices include minimum tillage, mulching, terracing and crop rotation (Knott, 2015).

Intensive agriculture typically aims at maximizing the output of land. Over-irrigation and fertilization can cause chemical elements in the soil to leach from the soil profile into the ground water where it is ultimately unavailable to the crops. For example, soluble nitrogen complexes such as nitrates can leach from the soil profile and percolate into the groundwater (Letey, 2013; Gomiero et al., 2011). The salinity of the ground water therefore increases often making it redundant for domestic or agricultural use. Consumption of the contaminated groundwater can ultimately be detrimental to human health, causing diarrhoea or possibly death (Okotto et al., 2015; Gomiero et al., 2011).

Where the infiltration rate of water into the soil is less than the rate at which water is applied to the soil, puddles can form on the soil surface which subsequently can lead to surface run-off (Hillel, 2004). Surface run-off accentuates the process of soil erosion, loss of soil organic matter and chemical elements. Much of the chemically rich run-off water can ultimately make its way to rivers, lakes or other natural fresh water bodies and catchments. The subsequent accumulation of agro-chemical elements in these water bodies can have deleterious effects on ecosystems as well as habitat of aquatic plant and animal species (Parris, 2011; Holmes, 1988).

Deforestation for the establishment of plantations is an age old practice. During the colonial and trans-Atlantic slave trade period between the 1500s and 1800s, plantations of crops such as sugar and tobacco were established in the Americas and the Caribbean islands at the expense of natural forests (Moore, 2010; Corbi & Strixino, 2008; Walvin, 2007). Today the same practices are observed at an even greater scale.

Tropical rainforests have been and are still being cleared for the establishment of plantations (such as sugar cane and palm oil) in developing countries. These include countries such as; Indonesia and Thailand, South American countries that harbour the Amazon, as well as African countries (Allen & Barnes, 1985 and Sheil et al., 2009). According to Clark et al. (2001) mature tropical moist forests are dense in vegetation and are therefore sinks for carbon dioxide for the planet. Loss of forests could lead to a faster accumulation of atmospheric carbon dioxide. Rainforests are also large suppliers of atmospheric oxygen; the Amazon forest alone is accountable for more than 20% of the oxygen produced on earth (Butler, 2008).

According to Penny (2009) 73% of Africa's agricultural drylands are degraded thus making the continent more susceptible to desertification. Desertification of agricultural land due to soil erosion is indirectly a major cause of deforestation. As agricultural land continually becomes degraded more forests need to be cleared for subsequent conversion to agricultural production systems (Pimentel et al., 1995). Countries significantly affected by drought and desertification in southern Africa include Zimbabwe, Namibia (not including the Namib Desert), South Africa and Botswana (Penny, 2009). Desertification can also lower the water availability if aquifers are depleted faster than they can be recharged in drought risk regions (Penny, 2009).

Honey bees are responsible for more than 90% of all commercial crop pollination on earth (Schmitt, 2014). The value added to the deciduous fruit industry alone, by managed honeybee pollination, falls within the wide range of ZAR 189-828 million, just in South Africa (National Agricultural Marketing Council (NAMC), 2008). Honey bee (*Apis mellifera*) populations in North American and European countries have reportedly been on the decline. Alleged contributors to this decline include climate change, diseases and chemical pesticides (Pettis et al., 2013). Furthermore several sub-lethal side-effects of pesticides on bees have been reported by researchers. According to Pettis et al. (2013), insecticides and fungicides can significantly alter the feeding behaviour, enzyme activity, mobility, offspring sex ratios and immune functioning (which will make bees more suscepitible to illness). Neonicotiondoid insecticide exposure to bees induced uncoordanited movements, tremours and hyperactivity in bees exposed to higher dosage concentrations (Blacquie`re et al., 2012)

It is important to mention that in the aforementioned case one can observe where it may become difficult for politicians to manage the use of chemicals. On the one hand loss of bees will lead to a chain reaction where losses in yields and subsequently income will be observed. On the other hand; regulating the use of agro-chemical biocides in order to protect bee populations can result in an increased incidence of plant based pathogens, which ultimately will result in the loss of yield and thus income. Farmers who omit agro-chemicals from their production systems and who are also dependent heavily on bees for pollination, may suffer losses caused by other parties if the state remains inert from adressing the issue.

The environmental repercussions of conventional agriculture are directly and indirectly costly to humans. These costs can be economic as well as social. Sustainably amending the environmental effects of conventional agriculture requires an objective and interdisciplinary approach.

2.4.3. Economic

The aforementioned social and environmental costs of conventional agriculture can often be expressed in terms of financial figures. According to Pimentel et al. (1995) corn yields can reduce by up to 65% on serverely eroded soils in the USA, and up to 80% in some parts of the Philipines. As previosusly mentioned the the biggest contributor to soil erosion is agriculture. According to Ananda and Herath (2003) the estimated annual losses in on-site crop productivity due to soil erosion stemming from upland farm activity amounted to USD 320 million in Java. Furthermore the aggregate cost of both on-site and off-site effects of soil erosion in the country is approximately USD 340- 406 million (Ananda & Herath, 2003). In India, the 6.6 billion tons of annually eroded soil containing approximately 5.4 million tons of fertilizer valued is at Rs. 2.2 billion (Ananda & Herath, 2003). The off-site impacts of soil erosion, including siltation, water pollution and agrochemical rich run-off can also become expensive to repair. Soil sediments can lower reservoir capacitance having adverse effects on irrigated agriculture and hydro-electric generation (Ananda & Herath, 2003). Therefore the costs of muncipal water treatment can be augmented as municipalities will be forced to invest in sedimentation basin, water filtration and purification technologies (Holmes, 1988).

The relative cost of fertilizers in South Africa, compared to the prices on the international maket, is higher (DAFF, 2015a). As seen in Table 2.1 and Table 2.2, all the major fertilizers were being sold at a lower retail price internationally than in South Africa for the years 2013 and 2014 respectively. Furthermore Figure 2.2 illustrates that the general direction of fertilizer prices in South Africa is upward. More noticeably, there was a surge in the cost of fertilizers in the year 2008. This spike coincided with the 2008 global fincial crisis as well as the highest price of OPEC crude oil that the world had experienced at that time; averaged at 94.1 USD per barrel (Statista, 2017).

Table 2.1: South African fertilizer cost

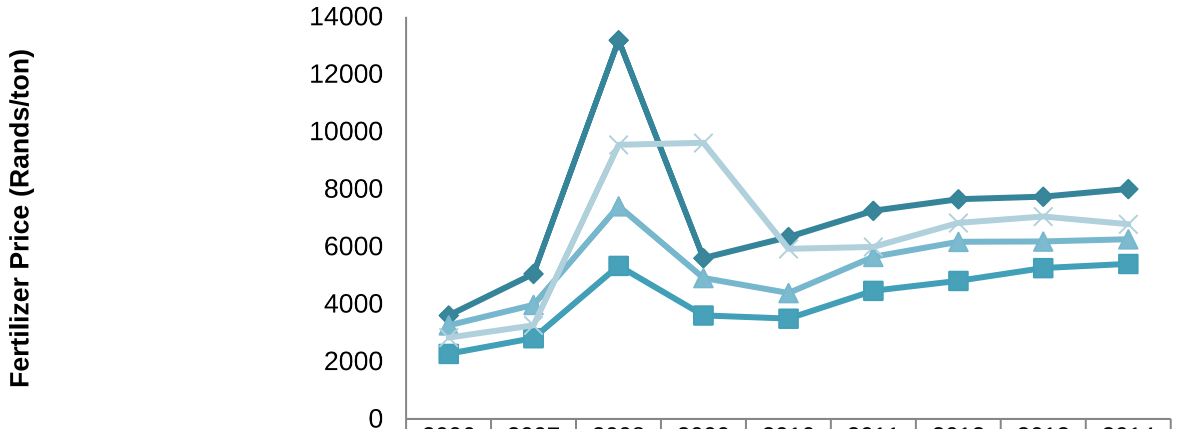
Fertilizers	April 2013 R/ton	April 2014 R/ton	%Change
KAN (Potassium Ammonium Nitrate)	5518	5590	1,3
Urea(46)	6456	6834	5,9
MAP (Mono-Ammonium Phosphate)	7456	8274	11
Potassium Chloride	7041	6989	-0,7

Source: DAFF, 2015a

Table 2.2: International fertilizer cost

Fertilizers	April 2013 R/ton	April 2014 R/ton	%Change
KAN (Potassium Ammonium Nitrate)	5069	5031	-0,7
Urea(46)	3809	3736	-1,9
MAP (Mono-Ammonium Phosphate)	4307	5247	21,8
Potassium Chloride	3789	3201	-15,5

Source: DAFF, 2015a



	2006	2007	2008	2009	2010	2011	2012	2013	2014
MAP	3603	5055	13188	5595	6337	7252	7646	7739	8004
KAN/LAN	2269	2818	5329	3606	3494	4462	4807	5254	5399
Ureum/Urea	3258	3972	7408	4913	4382	5640	6173	6181	6258
Potassium Chloride (granular)	2832	3255	9544	9615	5924	5988	6827	7049	6784

Figure 2.2: Average Fertilizer Prices in South Africa (2006-2014)
Source: DAFF, 2015a

As stated previously, the negative characteristics of conventional agriculture can be experienced both on and off the farm. The ripple effect of rising production costs (through more expensive inputs) eventually reaches the pockets of consumers in the form of inflation on food prices. This can have negative social implications where the livelihood of the people who earn the least will be effected the most.

Lastly, the micro-economy of a strictly conventional agricultural system can be heavily influenced by the activity and dynamism of the larger global economy. Canned pinapples produced in and exported from South Africa had to be sent back to the the country after elevated levels of carcinogenic cadmium, lead and arsenic were detected at the European port of entry (Gosling, 2007). This came at the expense of several farmers' and producers where rejects were counted as a loss. The cadmium originated from chinese chemical fertilizer imported and used in South Africa.

2.5. Organic agriculture

Much like the definition of conventional agriculture, organic agriculture's definition is complex. According to Gomiero et al. (2011), organic agricultural systems are characterized the by the exclusion and prohibition of agrochemicals, synthetic chemical additives and Genetically Modified Organisms (GMOs) from the production process. The International Federation of Organic Agriculture Movements (IFOAM) (2017) states that:

"Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved."

Since the initial use of the word "organic" by Walter Northbourne in 1940, propagation of the knowledge surrounding the organic agricultural concepts and principles has had its effect on both producers and consumers of food products. This coincides with the development of knowledge surrounding negative effects of conventional agriculture and the search for alternative methods.

2.5.1. Overview of regional organic agriculture markets for organic foods

Global Organic Food Market Forecast and Opportunities, 2020 (2015) projected an expansion of the organic food market at a compound annual growth rate (CAGR) of 16% between 2015 and 2020. Figure 2.3 illustrates that the retail sales of global organic products have grown from USD 15.2 billion in the year 1999 to USD 80 billion in 2014 (Sahota, 2016).

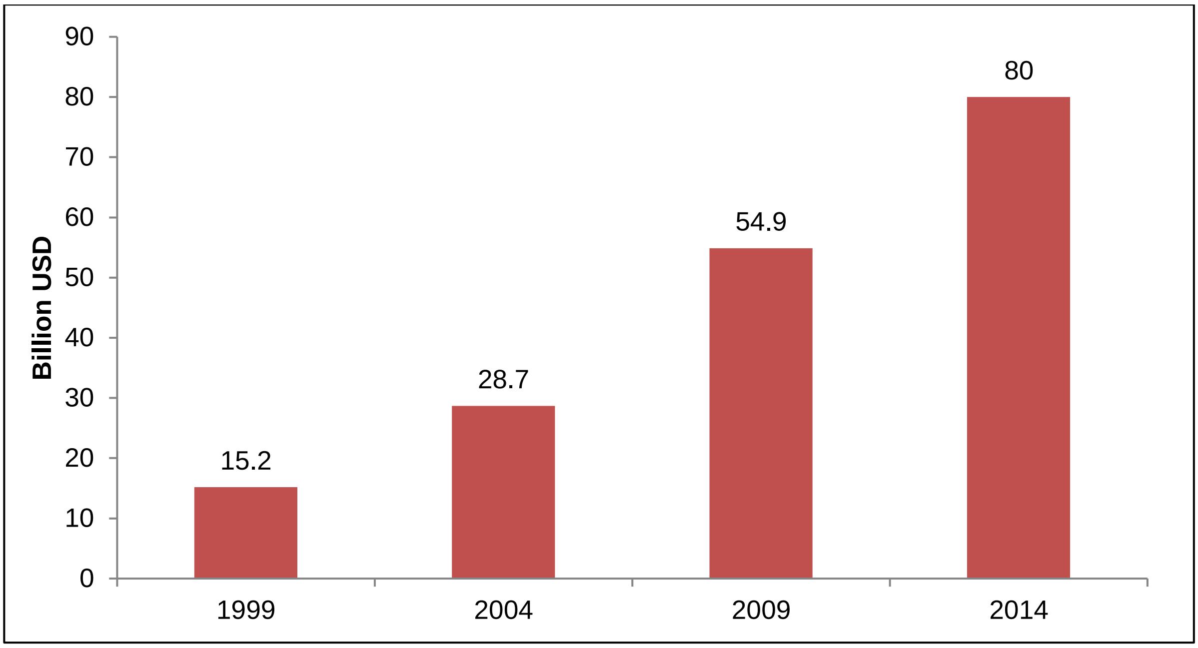


Figure 2.3: World: Growth of the global market for organic food and drink, 1999 - 2014
Source: Sahota, 2016

In 2014, the USA managed to generate USD 38.5 billion worth of retail sales of organic products sold for food and drink (Sahota, 2016). North America was the largest organic food market in the world for that year. Fresh products formed the bulk of the organic products that were sold on the continent, namely fruits, vegetables and dairy items. The USA offers much of its organic products on the export market. This has been aided by the government's establishment of organic equivalency agreements with other countries including Switzerland and Japan (Sahota, 2016).

Second to the USA, Europe holds an organic food and beverage market that has an annual value in the region of USD 35 million (Sahota, 2016). The leading nation when it comes to the money generated from organic items sold is Germany (valued at around USD 10.5 billion). Organic food sales are predominantly from supermarkets where private labels are widespread. The products sold are labelled uniquely by the store selling them. Anglamark and Naturaplan are two examples of commonly used private labels in Denmark and Switzerland respectively (Sahota, 2016). With multiple organic food shops springing up in Europe, large conventional supermarkets such as Rewe and their Temma chain, have ceased the opportunity to diversify toward inclusion of organic food items on their shelves (Sahota, 2016). Firms that produce and export are predominantly situated in Germany, France and the Benelux.

The third largest market for organic food products is Asia. Three million hectares of the Asian continent is being farmed using organic practices (Sahota, 2016). In land limited countries such as Japan and Singapore, much of the organic foods are imported from other nations. China is an exception where most of the local organic produce is intended for domestic consumption.

The number of certified organic farmers in South Africa was reported to be 250 in 2006 (DAFF, s.a.). This figure is actually higher as grower groups were considered as one farm (Kelly & Metelerkamp, 2015). Compared to Uganda, who had nearly 190 000 organic farmers in 2014 (Kelly & Metelerkamp, 2015), the figure representing South African famers is small. Furthermore the majority of organic farmers in Uganda operate on smallholdings whereas in South Africa, most of the certified producers managed large scale farms. These statistics may not necessarily represent a difference in the rate at organic principles are adopted in the respective countries. It may also represent different agricultural norms and socio-economics.

2.5.2. Benefits of organic agriculture

There is a plethora of unconventional agricultural systems that carry the fundamental aspects of organic principles. This means that the list of benefits attached to organic agriculture is extensive. For this reason the benefits of organic agriculture in any further discussions is restricted to organic crop production systems. Furthermore the benefits can also be discussed in terms of the three pillars of sustainability (economic, social, and environmental).

2.5.2.1. Economic

The organic food market is one of the fastest growing markets across the world with the USA and European countries experiencing the most growth and controlling 90% of the total market (Jouzi et al., 2017). In Europe this market is growing at an annual growth rate of more than 20% per annum (Whiriskey & Mc Carthy, 2006). The price for organic produce is typically higher than that for products that have been produced conventionally (Jouzi et al., 2017; Gillespie, 2012; Thompson & Glaser, 2001). This means that organic products, though typically more expensive to produce than conventional, are still economically competitive and lure the consumers if the market's growth rate is taken into consideration. The price premiums mean that farmers can maintain profitability despite relatively lower yields obtained from farming organically (Jouzi et al., 2017). An Indian comparative study on the economic profitability of organic and conventional farm systems showed that crop performance reduced by 9.2% with the introduction of organic principles. However, due to the 20-40% premium pricing of organic products coupled to the 11.2% reduction in input costs, farming organically raised the farmer's profit by 22% (Ramesh et al., 2010).

In the USA, it was found that the current premiums (and profit earned by organic farmers) on organic products could also be attributed to the laws of supply and demand. Organic products are in high demand but supply is limited (Oberholtzer et al., 2005). Market growth and farmers profiting from high premiums according to Oberholtzer et al. (2005), cannot continue forever for as long as the production of organic items remains profitable new producers will always be attracted to enter the fold. Subsequently in the long run one would expect the increase in supply to result in a decrease in the price of organic products. Such a scenario would benefit the consumer, whereas the producer would be subjected to forfeit profit made from the market's exclusivity. The aforementioned scenario was motivated by making reference to the organic dairy market in some European countries. Here the price premium on organic milk is now close to zero percent, due to the market's competition created by new producers (Oberholtzer et al., 2005). Oberholtzer et al. (2005) stressed that if any organic premium exists due to higher production costs than similar products produced conventionally, they will remain present even if the market expands. It is still holds that more research is needed to fully understand the components of the organic premiums (Oberholtzer et al., 2005).

Several completed case studies concluded that organic farming is a sustainable source of income, particularly amongst smallholder farmers in developing countries (Jouzi et al., 2017). However, access to financial risk management services, such as crop insurance, is not often accessible to small scale farmers in developing countries. Organic farming principles such as inter-cropping and rotation provide several avenues for smallholder farmers to generate income. This ‘market-flexibility’ provides farmers with some resilience to market fluctuations, thus giving organic farmers more economic sovereignty and less dependence on the proliferation of a specific commodity (Jouzi et al., 2017).

2.5.2.2. Environmental

Environmentally, organic farming adopts a holistic attitude toward agriculture with the purpose of achieving long-term environmental sustainability and less effect on nature (El-Hage Scialabba, 2013). Organic farming profits the environment by improving the natural biodiversity. Several studies have proven that more often than not, the measure of biodiversity on organic farms is significantly greater than that of conventional farms (Rahmann, 2011; Bengtsson et al., 2005). In the meta-analysis produced by Bengtsson et al. (2005) it was found that there was 50% more organisms on organic farms than on conventional farms. Furthermore there was a 30% increase in the species richness of an organic farm in comparison to conventional farms in the aforementioned study.

Due to the absence of synthetic agro-chemical inputs from the production systems, organic farms are particularly dependent on inherent soil properties for production. Organic farming systems can incorporate conservation agricultural techniques such as minimum tillage, terracing, cover cropping and mulching to help improve the soil properties for cultivation (Jouzi et al., 2017). It has been shown that soil organic matter in organic farming systems can be higher than that of conventional farm systems; the bonus in having higher soil organic matter lies in the potential augmentation of soil water retention and subsequent reduction in soil erosion (Ruiz-Colmenero et al., 2013; Jankauskas et al., 2007; Hillel, 2004).

Several organic crop producers use compost to supplement plant nutrition. This, often, cannot be avoided as the process of harvesting removes much of the essential elements for crop production from the soil. These elements need to be replenished if cultivation is to be continued perennially. The environmental benefits of manufacturing one's own compost is that it helps to close a nutrient cycle where the waste product of the same or another production system can be re-used as a nutrient input. Nutrients that otherwise would have been lost are re-cycled when compost is made and used. Unlike the elements in inorganic fertilizers which are readily available for plant uptake, much of the elements in compost are only brought into solution once the organic material has been decomposed and mineralization has occurred. This means that the likelihood of mineral leaching is lesser for composted soil amendments.

Climatic changes can pose a huge threat to all kinds of agricultural systems. The most vulnerable regions are where food insecurity is highest. Organic farming's ecological foundation means that the environmental footprint (i.e. greenhouse gas emissions, pollution etc.) left by organic agricultural activities ought to be less than that of conventional activities (Jouzi et al., 2017). Furthermore organic farming practices as previously mentioned can potentially improve the resilience of a farm system to drastic changes in climate, particularly small-holders in developing countries. Resilience to changes in climate can be achieved by planting multiple varieties of a crop or multiple species in the same production unit, a practice which is advocated by organic agricultural principles (Jouzi et al., 2017).

Organic farming practices can be included in the farm system that ultimately lowers the total greenhouse gas emission. In some cases soil amendments can augment CO_2 sequestration form the atmosphere by the soil (Jouzi et al., 2017). Biochar results from degradation of organic materials where heat is applied to the materials in the absence of oxygen (also known as pyrolysis). The fundamental difference between charcoal and biochar is that the former is used as a fuel for combustion, whereas the latter (biochar) is used help amend soils (Lehmann et al., 2011). The addition of biochar to soil, according to Dickinson et al. (2015), can be categorized as an agricultural improvement. Biochar has been linked to soil fertility related benefits such as; increasing the pH of acidic soils (Van Zwieten et al., 2010), and improved retention of soil nutrients through cation adsorption (Liang et al., 2006). These benefits can ultimately enhance crop yields. Biochar also offers the environmental benefits of sequestering atmospheric CO_2 (Lehmann, 2007). This means that organic agricultural practices can potentially have both environmental mitigation and climatic resilience purposes. Although biochar alone does not provide high quantities essential elements to the respective crops, several researchers have illustrated that biochar in combination with organic or inorganic fertilizers could result in the enhancement of the biochemical and physical properties of soil including crop performance (Trupiano et al., 2017).

2.5.2.3. Social

Practicing organic agriculture can be labour intensive however the labour requirement provides a possible avenue for the employment (Offermann & Nieberg 2000). In their study, Lobley et al., (2009) reported that 6.4 people were employed per organic farm business, compared to the 4.8 people employed on conventional farms in England. In the same study, 27% of organic farmers employed additional labour following conversion to organic. Furthermore, Häring et al. (2001) mention that committing to environmental goals in agriculture might appeal to tourists, which can indirectly increase employment in tourism due to ecological aesthetics.

Due to the premium often placed on organic products, and the lowered cost of inputs, farmers can potentially earn more money. The added income means that farmers may be able to purchase items that previously could not be afforded by farming conventionally. In an example, a study that was conducted in Kenya showed that farmers who produced tea on smallholdings were able to fund their medical and schooling costs as a subsequent result of their conversion to organic farming (Jouzi et al., 2017).

Organic farming also tries to inspire farmers to incorporate their indigenous and traditional farming methods into the production system (Subrahmanyeswari &

Chander, 2013; Villegas-Pangga, 2013). Co-operative organisation resulting from organic farming has been found to stimulate the empowerment of female farmers who otherwise would have been unable to access markets and services (Jouzi et al., 2017). Female participation in agricultural markets by means of organic farming is more easily achieved because organic farming often does not require a huge initial capital investment (Subrahmanyeswari & Chander, 2011; Farnworth & Hutchings, 2009).

It was mentioned formerly that organic farming principles advocate for the inclusion and use of several species and varieties in cultivation. The benefit of incorporating the concept of multi-cultures into crop production systems is that it can potentially increase the dietary diversity of subsistence farmers within the region of growers (Jouzi et al., 2017). What this notion suggests is that accessibility to various food products is also enhanced and therefore nutrient deficiencies is developing regions can be combated through organic farming.

Food safety of organic products, from a consumer perspective, can potentially be higher as several studies illustrate a higher concentration of chemical residuum on conventional products than that of organic (Jouzi et al., 2017). From a farmers perspective the banning of agro-chemicals from organic production systems implies that farmers are less likely to experience toxicities from any contact made with the respective chemicals (Jouzi et al., 2017). This is especially important in developing countries such as Ghana and India where agro-chemically related poisonings fatalities are highest (Meeghan, 2013; Magauzi et al., 2011; Pesticide Action Network (PAN), 2010).

In South Africa there are more than 3000 individuals involved in participatory guarantee systems (PGSs) (Kelly & Metelerkamp, 2015). According to Kelly & Metelerkamp (2015) a PGS is a quality guarantee that has been developed by local consumers. PGSs are platforms that are dependent on the active participation of stakeholders with the sole purpose of catalysing the exchange of information and social networking. Due to the cost of obtaining an organic certificate from a third party, PGSs are supposed to serve as a cheaper alternative whereby the criteria for obtaining a certificate are set by the local producers and consumers. This supports the dialogue between the consumer and the producer, thereby creating more transparency in the market.

2.5.3. Problems with organic agriculture

As seen with conventional agriculture, there are instances where organic production systems can prove to be unsustainable for both farmers and consumers. These shortcomings of organic agriculture will be presented in a similar fashion as previously illustrated with conventional agriculture i.e. through the lens of sustainability and the corresponding three defining pillars (economic, social and environmental sustainability).

2.5.3.1. Economic

In order for a product to be identified as organic the production system needs to be successfully audited by an accredited certification body in accordance with a specific certification standard. South Africa does not yet have its own certification body (Kelly & Metelerkamp, 2015). However, there are other internationally recognised certification bodies and standards that can be obtained within the country's borders. The strictness of the regulations listed by each certification body may vary slightly but the core restrictions (i.e. prohibition of GMO's, and synthetic chemicals) are consistent. For example the Ecocert Organic Standard (EOS) prohibits organic crop producers from using hydroponics (Ecocert, s.a.) whereas the United States Department of Agriculture (USDA) National Organic Program (NOP) fails to mention hydroponics for the production of crops at all (USDA, 2013). However both standards prohibit the use of GMO's and synthetic pesticides in organic crop production systems.

The financial cost of obtaining or renewing an organic certification licence on an annual basis can be a barrier to entry for prospective organic farmers; particularly smallholders (Stolze et al., 2012; Källander, 2008; DAFF, s.a.). The argument can be supplemented by the fact that the majority of the 250 certified organic producers in South Africa in 2006, were operating on a large scale (Kelly & Metelerkamp, 2015). This means that some farmers would be unable to sustain a profitable business. This is violating the prerequisite of economic viability in sustainable agricultural system as per the definition of sustainable agriculture, according to Allen et al. (1991).

Certification standards are useful to those consumers who hold sceptism about organic products. These standards may serve to re-assure the consumer that a product is in fact “organic”, thus securing the consumers trust (Oberholtzer et al., 2005). Furthermore, organic certification is also necessary for organic producers who are looking to sell on international markets (Jouzi et al., 2017 and Oberholtzer et al., 2005). The development of a national organic standard can contribute positively to an increase in organic food exports, and consequent improvement of farmer’s livelihoods. This was observed in Uganda and with the development of the East Africa Organic Standard (Kelly & Metelerkamp, 2015). Organic exports from South Africa continue to grow despite of the absence of a national organic standard. This is due the availability of other internationally accredited standards that already exist in the country (i.e. NOP and EOS). However the national organic standard can be essential to improving the vibrance in the local organic market (Kelly & Metelerkamp, 2015). The development of national or regional organic standards can be more relevant and beneficial as foreign standards from the EU and USA are not tinkered to the agroecological, climatic and socio-economic conditions of South Africa (Kelly & Metelerkamp, 2015).

Unpredictable weather, insect infestations and plant pathogens can severely reduce crop performances and final yields or quality (Hanson et al., 2004). The trade-off of excluding the use of agro-chemicals from the crop production system, and lowering the cost of inputs, is increased susceptibility to pest and pathogenic damage. Particularly damage from pests and pathogens that were previously controlled using synthetic agrochemicals. Although, Hanson et al. (2004) mentions, organic farmers use alternative methods for pathogen and pest control, they still lack the quick fix solution that is offered through the use of synthetic biocides. Synthetic agrochemicals are important risk management tools in conventional crop production systems. Farmers who fail to adequately adapt their cropping systems to manage these risks may fall victim to the mutual risks associated with both conventional and organic agriculture. Duram (1999) states that in the 2-3 year transition period after cessation from conventional agriculture and conversion to organic agriculture, the farmer does not receive a premium for his produce. This means that prospective organic farmers, who are conventional at present, will have to endure the cost of restructuring their farming operations without receiving the full returns on investments made for at least a couple of years. There are also the potential risks associated with the conversion to organic agriculture, without the comfort of quick fix solutions that are offered by synthetic agro-chemicals.

The total inputs used in organic production systems are supposed to be comparatively less than that for conventional production systems. The prices charged to consumers for certified organic products are somewhat higher compared to items produced by conventional means. According to Trewavas (2001) the main reason behind this reality is attributed to the relatively lower yields obtained through organic productions systems. Another reason would be that the land use efficiency for maximizing yield is also lower; hence more land is required to obtain the same yields as conventional systems. Therefore the effect is a more expensive product for the consumer.

2.5.3.2. Social

Although there have been negative effects from the use of conventional agriculture technologies, complete rejection of a technology also means the rejection of potential profit that could have been attained through its use (Trewavas, 2001). According to Derpesch (2004) cattle draught for soil tillage was first implemented by European farmers around 4000BC. The energy and time required by both the farmer and cattle meant that it was optimal to keep the plough frequency to a minimum for this reason. The introduction of the tractor, however, meant that the farmers would use less of their cattle's and own energy on ploughing; which subsequently had farmers increasing their plough frequency. Organic farmers often need tractors to till and prepare soil prior to establishing a plantation (Cervantes, 2016). In a narrative based study conducted by Cervantes (2016) in the Philippines, it was found that those organic rice producers who relied on ploughing with a tractor, had issues with; the price of fuel for tilling, the availability of the correct tools for preparing the soil and also the availability of animals useful for ploughing. Any farmers who need to plough, and opt to exclude the use of a tractor for ploughing, have to come to terms with the fact that the physical human labour and time demanded will be higher if there is failure to adopt an alternative solution. It will take longer and be physically more strenuous to achieve the same objective. The problem would become an issue of socio-economics, where the farmer (particularly on larger farms) would have to employ additional labourer(s), decide how much they ought to be paid, and determine the effect of the given wage on standard of living.

The government of South Africa’s ruling in favour of a national minimum wage of ZAR 20.00 per hour will become legislated as of 1 May 2018 (National Treasury: Republic of South Africa, 2016). Research by Piek and von Fintel (2016) shows that unskilled employment on larger farms grew after the state initially legislated for sectoral minimum wage in 1999. However, in the same study, employment on smaller farms declined as the cost of labour for small scale farmers suddenly became too high. What was concluded by Piek and von Fintel (2016) was that the minimum wage merely displaced farm workers, from smaller to larger scale operations, which are typically more financially stable. After the Sectoral Determination for minimum wages was implemented in 2003, productivity was also sustained with an increase in the use of machinery (Stanwix, 2013); which could place further stress on job security. The introduction of a minimum wage has been accused of widening the gap in agricultural ownership and therefore upholding socio-economic inequalities. The short-run response of displaced workers due to minimum wages seemingly intensified. In the long run, the agricultural shift is toward fewer (but far greater in scale than before) capital-intensive farms (Piek & von Fintel, 2016).The nature of organic farming is such that it is labour intensive and thus additional labour is unavoidable.

Access to information and extension services regarding organic agriculture is relatively scarce when compared to that of convenitional agriculture (Nicolay & Baker, 2012). In the USA, farmers consult with; agro-chemical companies, local government agencies and neighbouring farmers when it comes to aopting novel agricultural practices (Duram, 1999). However the extension and information provided by the aforementioned parties often falls outside the scope of organic agriculture. Hanson (2004) found that under many circumstances in the USA, organic farmers formed support networks amongst themselves and the rest of the community to help them communicate with information about organic agriculture amongst one another. The study found that conventional farmer’s were less dependent on such networks and thus were less likely to form bonds amongst each other. These support networks were also active in promoting organic agriculture within the region and in the establishment of consumer loyalty; which is advantageous for organic farmers experiencing depressed production periods. Although the notion of bonding and comradery may not seem problematic, the point in emphasizing that such bonds exist is to again highlight how important local social cohesion is when it comes to establishing an organic practice. What must also be stressed in these observations is the extent to which consumer cognisance of and involvement in regional organic agriculture can play a role in promoting local farmer produce.

The problem lies is in the lack of a neutral platform that allows such structures to be formed. This means that the farmers will have to be autonomous in establishing such networks considering state and private company involvement in organic agriculture is greatly diluted and more skewed toward conventional agriculture. A similar finding was found by Cervantes (2016) study in the Philippines, where organic rice producers had expressed problems with the availability of technical extension support services and the need for market support. Cervantes (2016) went on to conclude that such services needed to be established by both the state and private sector.

Considering the plethora of organic certification stardards that exist across the planet, the fundamental principles behind each standard are important. However, several questions arise as to who is responsible for drawing up the rules and regulations for each standard, what are the threshold criteria for defining an agriculutural product as organic and how these threshold values are determined.

2.5.3.3. Environmental

Organic certification standards prohibit the use of inorganic minerals from the production processes. The main source of plant essential elements is therefore in the form of green (plant based) or animal manure (Trewavas, 2001). The use of manure as a plant nutrient source in organic crop production systems is a frequent occurrence. Manure has the benefit of enriching soil N and P as well as earthworm and other microbial populations (Trewavas, 2001). However, using manure also has disadvantages. Firstly, manure breakdown in the soil cannot be synchronized with the crops' growth phases of (as is desirable) and therefore can continue throughout the growing season (Wu & Sardo, 2010 and Trewavas, 2001). The ploughing in of legumes and the prolonged breakdown of manure can potentially lead to nitrates leaching from the soil into fresh water bodies at similar rates to conventional agricultural systems (House of Lords Select Committee on European Communities, 1999). Also, the elemental composition of manure is inconsistent and therefore offers unpredictable nutritional supplementation for crop growth. Hay fed animals that are producing manure for use on organic farms and that are also vectors for the bacterium *Escheria coli* 0157:H7 (*E.coli*). E.coli has been reported to incubate the bacterium for a significantly longer period than animals reared conventionally on grain (Hovde et al., 1999).

The total biomass of weeds associated with the organic cultivation of spring cereals can outnumber that which is found for conventionally cultivated cereals by up to fourfold (Brandsæter et al., 2017). As with soil preparation, some organic farmers exploit the benefits of a tractor for mechanical weed control. The negative effects that excessive ploughing via tractor can have on the soil and environment have already been discussed for conventional agricultural systems and therefore also apply to organic production.

2.6. Conclusions

Chapter 2 discussed how the popularization of conventional agriculture was achieved and what one deems to be the biggest contributors to its widespread adoption. The contributing factors mentioned were the human population and social dynamics, GR technology development and industrialization as well as political dynamics locally and internationally. An outline of the shortfalls in conventional agriculture was subsequently made. Through the lens of sustainability these shortfalls were broadly discussed. The concept of organic agriculture was introduced and also objectively discussed and critiqued through the lens of sustainability. From the review made it was concluded that either agricultural system can be as sustainable or unsustainable as much as the other and that more unbiased trans-disciplinary evaluations need to be made when objectively substantiating the sustainability of an agricultural production system.

Irrespective of the novel cultivation method (organic or inorganic), it is true that in order for such a method to be adopted at such a widespread scale, government intervention through various socio-political influences is necessary. Coupled to the innovative ideas that emerge to address technical agricultural issues, there needs to be research which aims to determine the socio-economic as well as the environmental impact and relevance of technical research and novelties. In this way the sustainability of introducing and implementing new technology into agricultural production systems can be better evaluated holistically.

Chapter 3 : Models and Simulations

3.1. Introduction

Models are useful tools when it comes to representing and describing a real world system or process that cannot be directly observed or described (Knott, 2015). A model can be used to forecast real world scenarios; where the outcomes of changes within different components of a system can be assessed within a manageable time period (Knott, 2015; Hoffmann, 2010).

According to Rotmans et al. (2000), all scenarios are charactersised as being; (i) hypothetical when describing future possibilities, (ii) descriptive of processes that represent sequential events over a time period, (iii) comprised of causally linked states or events, and (iv) depicitive of a final state given an initial state of reference. All scenarios are designed to identify key future driving forces and their trends. Regarding modelling, scenarios are meant to encompass variation in the assumptions used to create models (van Ittersum et al., 2014). In agriculture, modelling or simulating envisaged futures of current systems is cheaper and less time consuming than actually designing an experiment in order to envisage what will happen. It is important to realize that a model is only a projection of a possible future scenario based on current and real quantitative inputs and assumptions.This chapter reviews the process of budgeting and modelling aystems for the purpose of simulating different agricultural scenarios.

3.2. Modelling

The process of farming in the real world is time and resource consuming. When one opts to observe a farm system for research purposes, doing so in real-time can become expensive and time consuming very quickly. Furthermore the intricacies and complexity within the farm system is not very easy to reproduce in the real world, without consuming a similar amount of time and resources. Models are therefore developed to provide a reduced and more manageable representation of an existing real life system. Taking into account any set of defined assumptions any model is meant to mimic the real world system as closely as possible (Knott, 2015). A common approach adopted by farm systems researchers is to create models of a real life farms where symbols in the models are denoted to represent reality (Knott, 2015).

According to Knott (2015) a model can either be deterministic or stochastic. Deterministic models will be the models of choice as the research aims to analyse a specific set of inputs to simulate and render a specific outcome. These types of models are characterised as being useful when entertaining a systems approach to research where all the relationships between the variables in the system being modelled are constant (Knott, 2015).

The approaches taken toward modelling and simulation should factor in the end goal. Typicallly the approaches can either be normative or positive. The latter approach is concerns itself with ‘what is’, ‘what was’ and ‘what will be’ (Knott, 2015; Hoffmann, 2010). With the aid of current and historical variables a positive model can be used to predict a specific outcome. In this way the positive apporach to modelling is suited to deterministic models due to the fact that the system’s nature is described as it is and not how it should be (Knott, 2015). Furthermore the problem statements can be proved as being either correct or incorrect, when given the empirical output data from positve models.

The usefulness and practicality of modelling real life farms systems rests in their ease of understanding by both farmer and researcher (Knott, 2015). Models offer tools for determining the possible outcomes (outputs) of adjusting, including or excluding inputs, from the system. Considering that modelling is highly dependent on mathematics, the development of computing software has aided the progression of modelling significantly.

3.3. Simulations

Simulations are essentially experiments that are completed by using a finalised model of a real life system. The simulations measure and forecast the possible output from the real system in different scenarios (Hoffmann, 2010; Strauss, 2005; Nance & Sargent, 2002; and Gallagher & Watson, 1980). The output data from the simulation is supposed to reflect through the model as closely as possible. In other words, the outcome in reality, whilst the given inputs and constraints are borne in mind. Simulations are therefore useful in assisting the modeller with making informed predictions about the farm based on existing knowledge and data (Knott, 2015).

3.4. Budgeting in the context of Modelling

Budgeting is a useful tool to agriculturalists that has been utilized since the inception of agricultural economics (Hoffmann, 2010). Using budgetary control to manage finances has several benefits:

- Budgets enable financial managers to quantitatively express their future intentions (Nugus, 2005).
- A budget can assist to ensure that the returns on investments are optimally achieved (Nugus, 2005).
- Successful budgeting can facilitate a cognisance of costs in an organization (Nugus, 2005).
- Budgets are simple to use and interpret, thus making them user friendly across disciplines, whilst being able to incorporate a lot of detail (Hoffmann, 2010).
- They can be used parallel with other holistic methods in evaluating needs, and actively used in research and decision making (Hoffmann, 2010).

Budgets can be used to diagnose the current financial state of a farm system or alternatively, used to forecast a possible farm financial outcome budget using available data and numerical inputs. In essence budgets can be used to simulate the micro-economic activity on a farm when key parameters and assumptions have been outlined.

3.4.1. Definition of budgeting

Financial planning of economies is often achieved through the process of budgeting. This is true for economies of all sizes from households and kiosks, to multinational enterprises and sovereign states. The definition of a budget is therefore subjected to variation among individuals and organisations and is dependent on the initial purpose of the budget's establishment. Abrahams (2012:16) stated that budgeting (according to IBM) is defined as:

"*planning distributed to individual areas of responsibility in a business*".

Jackson et al. (2009) stated that budgets are plans that are designed to deal with the acquisition and use of resources over a given period of time. The dissertation of Abdullah (2008: 9) also provides the Chartered Institute of Management Accountants (CIMA®) Official Terminology definition of a budget:

"*A quantitative statement for a defined period of time, which may include planned revenues, assets, liabilities and cash flows. A budget provides a focus for the organisation aids the co-ordination of activities and facilitates control*."

Abdullah (2008: 9) further provides a twofold definition of a budget, as described by the Australian National Institute of Accountant (NIA®):

Definition 1: *"A budget is a comprehensive plan in writing, stated in monetary terms that outline the expected financial consequences of management's plans and strategies for accomplishing the organization's mission for the coming period."*

Definition 2: *"A budget is a master financial document or a "blueprint for action" that set out the expected contribution from the operation or control of an organization in terms of anticipated cash flows or revenues and expected expenditures over a certain period of time"*

The initial two definitions describe how budgets can be useful assets for planning and controlling the finances of an institution for a period of time. The latter three definitions focus on how a budget can be used as a blueprint by individuals, enterprises and other organizations for guidance when it comes to managing the allocation and distribution of resources and finances. The budget therefore can also be used as a means to hypothetically forecast the financial position of an economy, should finance allocation be fashioned into a distinct shape.

3.4.2. Types of budgets

A few examples of budgets include cash budgets, income and expenditure budgets or capital budgets. A budget will be rendered as being redundant irrespective of the detail contained, if it fails to focus on a point of responsibility (Nugus, 2005). In agricultural production systems there are three commonly exploited types of budgets including the whole-farm budget, enterprise budget as well as the partial budget (El-Deep Soha, 2014). For the purpose of this research however, only the partial and enterprise budgets were reviewed as whole farm budgeting falls out of the scope of the objects.

3.4.2.1. Enterprise Budget

According to El-Deep Soha (2014) and the United Kingdom's Department for Environment Food and Rural Affairs (DEFRA) (2010), an enterprise can be any crop or livestock type that is cultivated and produced on a farm. Therefore an enterprise budget is a listing of all the income generated and costs included as a result of producing a specified enterprise on a farm. Hence the aim of the enterprise budget can be to determine the profitability of growing a particular crop on a farm (El-Deep Soha, 2014). Every enterprise budget depends on the unit of measure that from which it is developed (e.g. hectares). This type of budget is ideal for the comparing the profitability of different enterprises on a given farm. As with the whole farm budget, the enterprise budget is comprised of income, costs and profit (El-Deep Soha, 2014).

The fundamental differences between a whole farm budget and an enterpise budget are; i) only one enterprise is included in an enterprise budget (whole farm budgets include all enterprises), (ii) a single unit of measure is used for an enterprise budget (the entire farm is the unit of measure in a whole-farm budget) (El-Deep Soha, 2014). Listed in the enterprise budget are the total costs generated for that enterprise i.e. fixed input plus variable input costs.

3.4.2.2. Partial Budget

The resulting outcome from relatively small changes made in farm operational methods can be illustrated by using a partial budget (Dillon & Hardaker, 1984). Any major reorganizational changes on the farm will require a whole farm budget to be compiled. Partial budget analyses (PBA) can be used to ascertain whether the inclusion or exclusion of an input in the farming procedure will leave the farm more or less profitable. Hence the budget serves the purpose of assisting in deciding whether an input (or the adjustment to the application rate of an existing input) should be included in, or excluded from, the farming process (El-Deep Soha, 2014). Preparation of the partial budget will be advantageous when determining the net benefit of; (i) substituting enterprises on the same unchanged farmland area, (ii) adjusting the measure to which a specific technology is used on the farm and (iii) shifting to novel technology altogether (El-Deep Soha, 2014). The use of partial budgets therefore allows for the assessment of the costs and benefits accompanied with a technical adjustment in an enterprise within the farming operation (El-Deep Soha, 2014 and Horton, 1982). Only variable input costs are included in the partial budget; hence why the budget is named '*partial'*. Only the costs of production which vary between the farmer's current production practices and the proposed one(s) are included (El-Deep Soha, 2014 and Horton, 1982). The fact that partial budgets require only certain costs that are affected by the technological adjustments makes them simpler to compile than whole farm budgets (Dillon & Hardaker, 1984). Although partial budgets may be used to provide recommendations to farmers regarding the use of inputs, care must be taken to not rely solely on the budget constructed for one successful on-farm trial alone (Horton, 1982). Where circumstances allow, on-farm trials should continue perennially (depending on the crop) for several years in order to provide sound recommendations to the farmer with the assistance of the partial budget.

The procedure necessary to composing a partial budget is relatively straightforward and can be taught to extension officers as well as farmers (Dillon & Hardaker, 1984). A careful description of the farm technological change is required as the initial step in partial budgeting as confusion can often emerge regarding the nature of the technological and practical change (Dillon & Hardaker, 1984).

The change in farm profits where causality is due to the change in methods as illustrated in the budget, can be assessed by deducting the total losses (costs) from the total gains (revenue). In a hypothetical situation, a quotient with a positive value will be indicative a resulting profit from the proposed change, whereas a negative value will be indicative of a loss. The resulting value is dependent on the accuracy of the technical and financial data entered in the budget initially. It is not always possible or feasible to include in the partial budget, every aspect weighing on the decision as to whether or not the suggested adjustment should be carried out (Dillon & Hardaker, 1984). Hence it is necessary to therefore identify and express any non-monetary factors influencing the final decision (Dillon & Hardaker, 1984). When using a partial budget analysis as an extension tool to make recommendations to farmers, one should consider the goals and objectives of the farmer and hence thoroughly discuss the findings of the PBA (Dillon & Hardaker, 1984). In this way the ultimate and informed decision as to whether to include or exclude a practical adjustment to the farming system, based on the budgetary results, lies in the hands of the farmer. Any consequences resulting from the decision will predominantly bear weight on the farmer.

The simpler way to construct a partial budget is to compare the gross margin of an enterprise in its existing state with the gross margin of the same enterprise bearing the introduced technical adjustment (Dillon & Hardaker, 1984). Therefore the post-budgetary analysis will conclude that the scenario with the highest gross margin will be more profitable. Having said this, a higher gross margin and thus higher profitability may not be indicative of a more sustainable system. This is why it is important to state and define, in as much detail as possible, the financial and non-financial influences bearing on the final decision. Several precautions however need to be taken when using gross margin comparisons to complete partial budgetary analyses as there can be dangers when making assumptions based on the results. Firstly, expanding the production capacity of the most profitable enterprise based solely on the gross margin per unit land, does not always lead to a proportional increase in profit (Dillon & Hardaker, 1984). It is important to consider fully the constraints adhered to expanding an enterprise as the fixed costs are likely to rise correspondingly. Partial budget compilation should be carried out whilst explicitly considering the effect that the proposed change will have on fixed costs should the operation be scaled up. Another assumption commonly made is the assumption of linearity in gross income and variable expenses. Increasing the production area of an enterprise might produce varying results due to differences in soil fertility. This means that a crop will proliferate in some parts of production area and not so much on others thus causing income based on the yields to vary. Fertilizer amendments may be required to rectify these differences which will correspond to a higher fertilizer cost. When non-linearities are thought to be present it is recommended to use the method initially described.

3.4.3. Budget models and spread sheets

A business or organization that is looking to set a budget for a period of time may need to produce several sets of historical figures including past budgets. Budget models, which are essentially simulation models, can be built using spreadsheets where the various elements and components of the model are linked through mathematical, statistical or financial equations (Barrow, 2008). Care needs to be taken by the modeller when defining how the elements interact with and are related to one another on a mathematical level. The models can be used to determine what the effect on the budget will be, should any of the input figures be adjusted. The benefit of having the budget model computed in spread sheet format is that the mathematical equations are instantaneously solved after the input figures have been adjusted. Furthermore, the computerized book keeping system has a budgeting model framework built in; hence various scenarios can be tested by merely adjusting the figures in the same budget model. In essence what this means is that budgets can be classified as simulation models that are designed to function using the principles of accountancy as opposed to pure mathematics (Hoffmann, 2010). The main benefit as a research tool is that physiological or (and) relationships can be interlinked with the financial system. This is especially important when issues of sustainability are introduced. Alternative, more ecologically and socially sustainable practices can be introduced into the farm system and the model immediately shows the expected impact on profitability. The model thus provides the standard accounting reporting format to assess the impact of physical changes on profit margins.

3.4.4. Budgeting terms and definitions

The process of budgeting requires an understanding of the terms and definitions used in a budget. A complete understanding of the finances in a farming system is also necessary to compile a budget as accurately as possible. Therefore, record keeping of all financial transactions or farming activities that come at an expense or profit to the farm is essential. What follows is a list of terms used in partial, enterprise and whole-farm budgets and their corresponding definitions.

3.4.4.1. Fixed costs

The portion of the total costs which cannot be avoided in the short-term, and are inherent in the production system, irrespective of the production scale (Noreen et al., 2009). This includes organic certification licences, regular labour and rent. When a financial comparison of budgets is made between a farmers' present technology and a novel technology, the fixed costs are the costs that do not change between the two budgets (El-Deep Soha, 2014; Kahan, 2013).

3.4.4.2 Variable costs

Unlike the fixed cost, variable costs are the costs that vary, usually in correspondence with the scale of the enterprise (Kahan, 2013). Variable costs are also costs which can be manipulated and controlled. Casual labour, fertilizer and pesticide inputs are examples of costs which are considered as variable (Kahan, 2013). When a financial comparison of budgets is made between a farmers' present technology and a novel technology, the variable costs are associated with the technologies being assessed.

3.4.4.3. Directly allocatable costs

These costs are any fixed or variable costs of an enterprise that are included in the enterprise and do not have to have a detailed record (DAFF, 2015b). Variable directly allocatable costs include seeds, fertilizer and pesticides sprays (DAFF, 2005). Fixed directly allocatable costs include depreciation on utilitarian implements. These costs are only necessary for whole farm budget models. What follows are the steps for calculating directly allocatable costs that were incurred upon during the research. The costs are listed with respect to the crop produced. Before these steps can be describes the assumptions made must be laid out.

3.4.4.4. Gross Value of production

The value of production from an enterprise on a farm is known as the gross value of production (GVP). The GVP figure considers only the marketable output from the enterprise (DAFF, 2005). Gross sales, insurance pay-outs (claims received due to crop losses), donations, household consumption and produce consumed by labourers are included (DAFF, 2005). GVP can also be calculated for a whole farm by summing together the GVP of each enterprise on the farm including the sundry farm income.

3.4.4.5. Gross margin

The gross margin (GM) of an enterprise is the difference between the GVP and the variable directly allocatable costs per area unit of production (i.e. one hectare for crops) (DAFF, 2015b; Kahan, 2013; DAFF, 2005). The whole farm budget incorporates all fixed and overhead costs whereas the GM budget only focusses on variable costs concerned with the specific products production (Knott, 2015). Fixed costs remain constant regardless of the level of output, whereas the variable costs are subject to change based on the scale and intensity of production (Knott, 2015).

GM budgets allow for the comparison of different enterprises performance in terms of profitability on a particular farm (Kahan, 2013). The information provided can assist the decision maker on a farm by projecting the financial implications when certain components of the system are manipulated (Kahan, 2013). The variable cost items included in the budget must be specified because their inclusion depends on the purpose of the calculation and the practical feasibility of the allocation.

3.5. Conclusions

Budgets can be used as models to assess the financial status of a farm. Models of the farm in the future can be created by computing simulations based on given scenarios. By analysing and comparing projected gross margins from enterprise and partial budgets farmers can either decide to include or exclude a change in the farm system. In this way farmers assess whether or not a realistic input change is financially feasible. Chapter 4 puts the theory regarding models, scenarios, simulations and budget analyses into the context of this research.

Chapter 4 : Methods and Materials

4.1. Introduction

It is always optimal to have a thorough technical understanding of novel farming techniques and technologies prior to including them in the farming system. The concern with new farming approaches, which work at a functional level, is whether or not they will be manageable at a systems level when introduced in the production process.

The financial feasibility of a farming approach that improves yield needs to be critically reviewed. If a new technology or farming approach does not make financial sense to the farmer then implementation of the strategy would contribute to financial suicide due to economic unsustainability.

Chapter 4 commences with a description of the physical farm where the experiment was conducted. The direct inputs of the parallel research project are described. Furthermore the scientific or technical elements and components of the research project are also described. The methods used for interpreting the financial feasibility of each treatment are discussed along with a provision of necessary assumptions. The calculations behind the respective costs that were rendered throughout the trial and whole research project are described within the context of the relevant enterprise and the type of cost being defined. Throughout the modelling phase, standard accounting principles are applied.

4.2. Physical description of the Farm

Before the model construction phase the physical description of the farm was defined. From this base farm all assumptions can be made thereafter.

The 0.4ha farmland is located 15km south of Stellenbosch in the Western Cape Province of South Africa near a rural dwelling named Raithby. Geographically, the co-ordinates of the small-holding are 34°01'10.4"S 18°47'20.6"E, with an elevation of approximately 95m above sea level. A map of the farm's location is provided in Annexure A.

The climate within the region is warm temperate where mean annual rainfall is 650mm (received mainly in the period from June-August). The availability of sufficient water after the trial is uncertain as severe water shortages were prevalent in the 2017 growing season. Regardless, the models built were based on the assumption that sufficient water was available for the duration of the cropping season.

The soil on the farm and thus experimental site has been classified as being a relatively shallow (40-50cm) Wasbank soil form which is part of the Lynedoch family (Gobozi, 2016). Previously (for more than 3 years) the site was left fallow where Kikuyu (*Pennisetum clandestinum)* grass was the predominantly crop species observed (Gobozi, 2016).

4.3. Description of the underlying scientific study: Phase I

The biophysical study investigated crop performance in response to different fertility and nutritional soil treatments. This study was carried out by Aron Mabunda (Farmer) and Sikho Gobozi (Soil Scientist) as part of a master in soil science. The study also assessed several biophysical soil properties and their dynamics in response to the respective soil amendments applied as treatments. The treatments involved amounted to six in total for each of two crops. These included; one control, one inorganic fertilizer treatment supplied by Yara and four organic soil fertility amendments, typically used by organic farmers. Throughout both of the growing seasons, before and after the sowing of seeds (seedlings) and applying the amendments, each experimental unit and plot was managed as closely and practically as possible to the standard practices applied by the farmer outside of the experimental conditions. Some of the results stemming from this technical phase were essential for establishing a basis to provide a financial meaning behind the data obtained. What follows in the subsections is a description of Phase I with respect the information that was relevant to the study in Phase II. An extensive and more detailed account of all the procedures can be found in Gobozi (2016).

4.3.1. Broccoli (*Brassica oleracea var. italica)* production

Initially, for the first winter season of 2016, broccoli (*Brassica oleracea var. italic*) was planted. A total of three different composts were produced and evaluated namely: (1) affordable commercial plant-based compost, (2) animal and plant waste compost produced by the researchers and farmer, and (3) pinewood biochar compost made with animal and plant waste.

The typical compost application rate of 10 m^3/ha used by the small-holding farmer (Aron) was evaluated (for all three composts). A commercial application rate of compost based on the N requirement of the crop (animal and plant waste compost only) was added.

The fertilizer treatments that were evaluated are as follows:

1. Control treatment (no compost or fertilizer)
2. Plant-based commercial compost from Reliance® applied at a rate 10 m^3 per ha
3. Manure and plant compost (made by farmer and researchers) applied at a rate of 10 m^3 per ha
4. Biochar, manure and plant compost (made by farmer and researchers) applied at a rate of 10 m^3 per ha
5. Manure and plant compost applied at recommended N application rate (300 kg N/ha) crop (i.e. 22t/ha)
6. Commercial fertilizer programme

Each treatment was replicated three times in a completely randomized block design. A land space of 112m^2 was used to accommodate the 18 plots measured at 4m^2 each. The productive area was only 3m^2 (1m^2 was treated but unplanted and reserved for soil analyses). A schematic presentation of the experimental layout can be found in Annexure B.

After 12 weeks, when the cropping season concluded, the yields (mass) and crop mineral status were scientifically determined. Extensive soil laboratory analyses were also carried out for each treatment throughout the growing season. The mature marketable broccoli heads were harvested from each plot and weighed.

4.3.2. Bush (green) Bean (*Phaseolus vulgaris*) production

On a new site, of 9.5 x 13.5m^2, the seeds that were sown for the second growing season (summer [February] of 2017) were that of bush (or green) beans (*Phaseolus vulgaris*) (Star 2000 supplied by Stark Ayres®). Adjustments to the soil treatments were made to accommodate the specific requirements of the crop according to Yara. Again six treatments were applied, some of which differed slightly from the treatments applied to broccoli. Each treatment was applied at 158kg nitrogen per hectare (158kgN/ha) and replicated three times in a completely randomized block design. Furthermore the quantities of the treatments applied were proportionally scaled down to fit the experimental plot sizes of 5m^2, where the productive area was 4.2m^2 (0.8m^2 was treated but unplanted and reserved for soil analyses). A schematic presentation of the experimental layout can be found in Annexure B. The treatments that were assessed for this leg of the trial are listed as follows:

1. Control treatment (no compost or fertilizer)
2. Commercial organic fertilizer with high nitrogen (Talborne Organics 74gN/kg))
3. Commercial organic fertilizer with low nitrogen (Bioganic 26gN/kg)
4. Plant-based commercial compost applied at a rate 10 m^3 per ha from Stellenbosch University
5. Commercial fertilizer programme (Yara)
6. Compost made by the farmer

As with the case of broccoli, once the cropping season concluded after 12 weeks the yields (mass) and crop mineral statuses were determined for the beans. Extensive soil laboratory analyses were again carried out by Sikho for each treatment throughout the growing season. The mature pods were harvested from each plot and subsequently weighed and prepared for laboratory analyses.

4.3.3. Data for input in the financial models

The scientifically validated data from Phase I was used directly as a basis for the final evaluation of the financial models. A positive approach to modelling is appropriate for this research due the prospect of determining and simulating the economic effects of using different variables (fertilizers) in farm enterprises (i.e. bean and broccoli production). The following section describes the use of financial models a research tools.

4.4. Description of financial study: Phase II

4.4.1. Information transferal and communication

Due to the involvement of several role players in the project, it was essential to establish a solid ground for multi-directional communication between the farmer, crop scientist and economist involved in the research project. A neutral medium of communication that involved the three members of the project was necessary to acquire the necessary financial and scientific information essential to the completion of the budget models. For this purpose, the main platform that was established for the frequent communication and exchange of information between the three parties was the cellular communication application WhatsApp. Using this application a group which included all three members of the project was started. On the WhatsApp group several images of product labels, receipts, vegetable prices and quotes were posted for all the active members to see and refer to when needed. The platform was also used to set up meetings in the case where mobile or electronic communication was inadequate for accessing information from one or another group member. It also provides a log record which is useful in the reporting phase.

4.4.2. Assumptions

4.4.2.1. Standardising units and scaling up

All the costs incurred as well as the revenue obtained were scaled up to one hectare units for comparison. This meant that the units of comparison were standardised for uniformity in order to make non-skewed comparisons; therefore justifying the action.

Hence the assumption that conditions before scaling up remained constant even after scaling up was accomplished (even though in reality this is not the case), was held.

4.4.2.2. Gross value of production

The gross production value was calculated for each treatment (where the masses obtained from each plot per treatment will be summed) using the mass obtained from the seasons yield and the selling price per kilogram of produce. The resulting value was then scaled up to produce a GPV per hectare. The assumption that the growing conditions and environment remained constant and reproduce the same yield after scaling up was borne in mind. Hence the calculation for the GPV per treatment is as follows:

$$GVP(ZAR) = \frac{\sum(\text{mass obtained from each plot per treatment})(\text{kg}) \times (\text{selling price})(\text{R/kg})}{(\text{productive area of treatment plot} \times 3)\ (\text{m}^2)} \times 10000\text{m}^2$$

kg = mass in kilograms
m^2= area in square metres
3= number of replications for respective treatment
R= rands (ZAR)

In this research study each enterprise only generated income through the harvesting and selling of the fresh produce at the end of the growing season. This is the only way in which any income was obtained. In creating the model the assumption was held that all the produce that left the farm was able to be sold in order to provide the estimated GVP values. The possibility of post-harvest losses was not factored into this research

The selling price was determined by selecting the retail selling price of broccoli at the time. Loose broccoli was sold by two local retail stores for R39.99 per kg in April 2017 and R24.99 in May 2017. The farmer normally sold his broccoli for R35.00 per kg. The farmer’s selling price fell within the range of prices that the aforementioned retailers had set for conventionally produced broccoli. Hence R35.00 per kg of broccoli was selected as the base selling price of broccoli for all treatments. This base selling price is used to determine the premium selling prices that would be used to run scenarios for the sale of organically grown broccoli.

Bush beans were sold at R35.00/kg in retail stores on 11 May 2017. This was the same price that the producer sold his organic beans for. Thus R35.00 per kg was the selected value for determining the GVP of bush beans produced by all the treatments as the first basis of comparison. As with the case of broccoli, the aforementioned selling price would then be used to determine the premium selling prices that would be used to run scenarios for the sale of organically grown bush beans.

The budget analyses for organically treated commodities were also carried out using the retail selling prices. Further analyses on organic partial budgets were carried out by including a minimum premium and maximum premium. However the premiums will be discussed later.

4.4.2.3. Land, inventory and capital

It was assumed that the farmer was given autonomy (either of his own or another person's accord) to cultivate the land according to his own will. Hence the cost of acquiring the land or renting it for cultivation from a third party was zero.

Another assumption was that the farmer had regular access to the tools and inventory needed to successfully cultivate the crops: from the initial sowing or transplantation, until harvest. Such items (amongst others) includes spades, rakes, garden forks, hoses, irrigation pipes and sprinklers, a pesticide dilution tank, a wheel barrow, watering cans and measuring tape.

It was also assumed that the land was flexible enough to convert from conventional to organic agriculture with little to no resistance. In other words the cost of restructuring the farm system was considered as negligible.

4.4.2.4. Transport

Transport costs for production were insignificant and were therefore omitted. The reason is that no external inputs were required in the production process.

4.5. Broccoli production

4.5.1. Seedlings

Seedlings were purchased from a local organic farmer as the seedlings that were grown in the farm's nursery were ridden with pests and diseases. Two full trays of seedlings were bought at R200.00 each. Thus each broccoli seedling cost the farmer R1.00. Furthermore 20 seedlings were transplanted into each of the 18 experimental plots. Hence the per hectare cost of broccoli ("Cost(br)") seedlings were calculated as follows:

$$\text{Cost(br)} = \frac{\text{cost of seeds per plot (R)}}{\text{size of production area of plot}(\text{m}^2)} \times 10000(\text{m}^2)$$

R= Rands (ZAR)

m^2= square metres

(the production area of the plot was 3m^2).

4.5.2. Fertilizer and organic treatments

4.5.2.1. Control

The control had no fertilizer cost as no treatment was applied. Therefore there was no input value included for the fertilizer cist in the budgets.

4.5.2.2. Inorganic chemical fertilizer

The inorganic fertilizers bought from Yara were priced according to their recommended application rates for cultivating broccoli. Table 4.1 provides is a list of all the inorganic treatments (that together form one experimental treatment) and their recommended rates according to Yara:

Table 4.1: Yara Fertilizer prices and recommended application rates for broccoli.

Fertilizer	**Price (2016) (R/kg)**	**Recommended fertilizer amount needed for broccoli (kg/ha)**
Superstart	R 6.15	600
Turbo 31	R 5.26	200
Nitrabor 30	R 5.46	325
Top up	R 5.93	475

Source: Gobozi, personal communication, 2017

The cost of each inorganic treatment was the product of the price and the recommended fertilizer amount needed. The sum of each value was then used to obtain a grand total cost for the inorganic fertilizer treatment. The equation used to determine the total cost of the inorganic fertilizer ("Cost(fert)") treatment listed in table above is as follows:

$$\text{Cost(fert)} = \sum [\text{Price(R/kg)} \times \text{recommended fertilizer amount needed for broccoli(kg/ha)}]$$

4.5.2.3. Commercial compost

The compost sold by Reliance cost the farmer R80.00 per 30 kg bag. An application rate of 10tons per hectare was used for this compost and applied as an experimental treatment and thus soil amendment. The equation that was used to calculate the cost of this compost ("Cost(cc)") per hectare is as follows:

$$\text{Cost(cc)} = \frac{\text{Price (R/30kg)}}{\text{30kg}} \times 10000\text{(kg)}$$

4.5.2.4. Composted waste

The materials used in the composted waste were grass clippings and cattle manure. This compost was produced at Welgevallen experimental farm in Stellenbosch and the ingredients were freely available, and on a regular basis. A pile of compost was produced, before it was subsequently divided proportionally for use in the other three compost dependent treatments. These include composted waste mixed with 20% biochar by mass, composted waste at 22t/ha (commercial rate equivalent to 300kgN/ha) and composted waste at 10t/ha (farmers application rate). The summary of the treatments and application are found in Table 4.2.

Table 4.2: Experimental rates of composted waste treatments.

Compost treatment	**Application rate (tons/hectare)**
Composted waste	10 (farmers application rate) 22 (commercial rate equivalent to 300kgN/ha)
Composted waste and biochar (20%)	10 (farmers application rate)

Source: Gobozi, personal communication, 2017

The compost took eight weeks to make and reach maturity. Once every week the compost pile was turned and this took approximately one hour per week. Given the fact that the compost materials were provided for free the cost of the compost itself rested entirely in the cost of farm labour per hour. This cost however was not recorded as the farm labour cost but rather as a compost cost. As previously mentioned the cost of farm labour per hour was ZAR 14.25 at the time of calculating the compost cost. The following equation was thus used to determine the cost of making the big pile of compost:

$$\text{Compost labour cost} = \text{R}14.25 \times 8\text{hours}$$

The compost pile was separated into to two uneven piles where approximately two thirds of the materials was used to make the two composted treatments (22 t/ha and 10 t/ha) and the remaining third (or the other pile) used to make the treatment consisting of both composted waste and biochar (10 t/ha). The relative cost per hectare of manufacturing the treatment comprised of a mixture of biochar and composted waste and was calculated with the aid of the following equation:

$$\mathrm{Cost(bio)} = \frac{\frac{1}{3} \times \mathrm{R14.25} \times \mathrm{8hours}}{\mathrm{4m^2} \times 3} \times \mathrm{10000m^2}$$

For each of the respective treatments involving the composted waste, the entire area of $4\mathrm{m}^2$ per plot received the treatment which was replicated three times. The remaining pile that consisted of two thirds of the initially composted material was again divided such that one pile was used for the composted waste treatment at 22t/ha and the composted waste treatment applied at 10t/ha. Hence the following equations were used to determine the relative cost of each:

$$\mathrm{Cost(22t/ha)} = \frac{(\frac{2}{3} \times \mathrm{R14.25} \times \mathrm{8hours}) \times \frac{\mathrm{22t/ha}}{\mathrm{32t/ha}}}{\mathrm{4m^2} \times 3} \times \mathrm{10000m^2}$$

$$Cost\ (10t/ha) = \frac{(\frac{2}{3} \times \mathrm{R14.25} \times \mathrm{8hours}) \times \frac{\mathrm{10t/ha}}{\mathrm{32t/ha}}}{\mathrm{4m^2} \times 3} \times \mathrm{10000m^2}$$

4.5.2.5. Organic pesticides

One litre (ZAR 140.00) of Neem oil was needed to control pests (worms). The recommended application rate is one litre per hectare and Ludwig's insect spray was used twice to combat insects and costs ZAR 262.00 per litre. Two litres per hectare is the recommended application rate (Gobozi, personal communication, 2017). Hence the total cost of using organic pesticides was the sum of the recommended dosages per hectare.

4.5.2.6. Seasonal farm labour

As previously mentioned, calculating the cost of farm labour excluded the cost of manufacturing compost. In the context of this research farm labour included all manual farming activities that were inherently necessary in order to complete the production season irrespective of which input (i.e. fertilizer treatment) was applied. Farm labour entailed activities such as bed making, weeding harvesting, fertilizer application, sowing and the application of organic pesticides. The fact that nobody was hired to tend to the farm meant that there were no payslips to use as a reference. Furthermore the general maintenance of the farm for the first growing season rested entirely in the hands of the researchers and the farmer.

It took approximately two full working days to prepare the beds for planting. Hence a total 16 hours was worked assuming that a full working day consisted of eight hours. The following equation was used to determine the pre-seasonal labour cost for the experimental area of $112m^2$:

$$\text{Pre} - \text{season labour cost} = 16\text{hours} \times \text{R}14.25$$

The way in which seasonal labour was estimated was by using the number of visits that were made to the farm by the researchers per week to do farm work. Table 4.3 below is summary of that estimate:

Table 4.3: Breakdown of seasonal farm labour cost.

Weeks	**Visits per week**	**Hours per visit**	**Minimum hourly wage (2016)**
12	2	1	R 14.25

Source: Gobozi, personal communication, 2017; Own analysis

Two visits were made to the farm for the duration of the growing period in order to attend to the experimental unit. The weeding and spraying of pesticides as well as applying of treatments were carried out. In order to determine the cost of labour within the growing season the following equation needed to be solved:

$$\text{Seasonal farm labour cost} = 12\text{weeks} \times 2 \times 1\text{hour} \times \text{R}14.25$$

Harvesting occurred on a weekly basis over a period of four weeks. Approximately two hours were spent on the experimental area each time where the yields from each respective treatment were acquired from the three plots collectively. The following equation was solved to determine the aggregate cost of labour in all phases of production (“Sum(lab)”):

$$\text{Sum(lab)} = \{[12\text{weeks} \times 2 \times 1\text{hour}]_{\text{a}} + [2\text{days} \times 8\text{hours}]_{\text{b}} + [2\text{hours} \times 2\text{people} \times 4\text{weeks}]_{\text{c}}\} \times \text{R}14.25 \times \frac{10000\text{m}^2}{112\text{m}^2}$$

Subscripts:

a= the in-filed labour required within the growing season by 1 person

b= the in-field labour required before the growing season by 1 person

c=the labour required for harvesting by 2 people

4.6. Bush bean (green bean) production

4.6.1. Seeds

The per hectare cost bush bean seeds that were purchased from Agrimark farm store was calculated as follows:

$$Cost(seed) = \left[\frac{\mathrm{R171.01}}{\mathrm{500g}}\right]_{\mathrm{a}} \times [\mathrm{0.46g}]_{\mathrm{b}} \times [\mathrm{2160seeds}]_{\mathrm{c}} \times \frac{1}{[\mathrm{4.2m^2} \times \mathrm{6treaments} \times \mathrm{3replications}]_{\mathrm{d}}} \times \mathrm{10000m^2}$$

Subscripts:
a= cost per gram of seeds
b= average mass of one seed (g)
c=number of seeds sown
d=total production area for trial (m^2)

The container of seeds produced by Stark Ayres cost ZAR 171.01 per 500g; thus the average price of seeds per gram was determined. The average mass of a single seed was determined by weighing 28 seeds on a digital scale; this value (0.46g) was then multiplied by total number of seeds sown for the 18 plots (2160) in order to determine the total gram mass of seeds planted. The product of the previous multiplication was subsequently multiplied by the average cost per gram of seeds, and subsequently divided by the total production area of the trial. This value was then scaled up to provide a price per hectare.

4.6.2. Seasonal farm labour

During the production season of green beans one labourer was employed. The general farm work, which was completed by the researchers before and during the production season of broccoli, was carried out by the labourer in the case of green beans. The farm was only using approximately one third of the total capacity. Considering that the farm size was approximately 0.4ha, per hectare costs of farm work that was required for the season was calculated as follows:

$$\mathrm{Labourer(cost)} = \mathrm{14weeks} \times \mathrm{R750.00} \times 3 \times \frac{1}{\mathrm{0.4ha}}$$

The total cost of labour also included preparation before sowing and harvesting labour.

4.6.3. Fertilizer and organic treatment costs for bush bean production

4.6.3.1. Control

As with the broccoli, the control treatment for bush beans had no fertilizer application. Therefore there was no input cost for fertilizer in the budgets.

4.6.3.2. Commercial Compost

For the purpose of the trial the commercial compost that was produced at Welgevallen experimental farm at the University of Stellenbosch was received free of charge. Under regular circumstances, the university produces and sells the compost for a profit. Therefore, should the farmer opt to frequently use this compost treatment post cessation of the research project, it is likely that he would have to pay for it. Nonetheless, 30kg of compost was received; which would normally be sold for R 25.00 (Gobozi, personal communication, 2017). This bag was sufficient enough to meet the 158kgN/ha application rate that was being tested at the time of the trial for all three experimental plots.

4.6.3.3. Farmer's compost

The own produced compost comprised primarily of grass clippings, hay from the farm's chicken pen and chicken litter. By definition it is by no means compost. The treatment acquired the name due to the lack of a suitable alternative. Furthermore any cost was considered to be negligible as it was not manufactured by anyone.

4.6.3.4. Inorganic chemical fertilizer

The inorganic fertilizers bought from Yara were priced according to their recommended application rates for cultivating bush beans, similar to the way in which the inorganic fertilizer was priced in the preceding section on broccoli. Table 4.4 presents a list of all the inorganic treatments (that together form one experimental treatment) and their recommended rates according to Yara:

Table 4.4: Yara Fertilizer prices and recommended application rates for bush beans.

Fertilizer	**Price (2017) (R/kg)**	**Recommended fertilizer amount needed for bush beans (kg/ha)**
Superstart	R 6.46	600
Turbo 30	R 5.64	150
Nitrabor 30	R 6.00	300
Top up	R 6.24	300

Source: Gobozi, personal communication, 2017

The cost of each inorganic treatment therefore will be the product of the price and the recommended fertilizer amount needed. The sum of each value was then used to obtain a grand total cost for the inorganic fertilizer treatment. The equation used to determine the total cost of the inorganic fertilizer treatments listed in Table 4.4 above is identical to the equation that was used to calculate the cost of the inorganic fertilizer treatment ("Cost(fert2)") for broccoli:

$$\text{Cost(fert2)} = \sum [\text{Price (2017)(R/kg)} \times \text{recommended fertilizer amount needed for bush beans (kg/ha)}]$$

4.6.3.5. Talborne and Bioganic organic fertilizers

Talborne was one of the commercially available organic treatments and soil amendments that were tested in the research project. When this treatment was compared to others in the same enterprise it was characterised as having a relatively higher concentration of nitrogen by mass (0.074kg/kg).

Bioganic All Purpose was the other commercially available organic fertilizer that was tested. Unlike Talborne the latter was characterised as having a lower nitrogen concentration by mass (0.026kg/kg). A greater mass of Bioganic fertilizer needed to be applied to the soil in order to meet the treatment level of 158kg N/ha (nitrogen per hectare). The following table is a summary of some key characteristics of the two aforementioned products:

Table 4.5: Price, nutrient composition and experimental application rates of organic fertilizers.

Organic fertilizer	Cost of fertilizer (R)	Mass (kg)	Nitrogen content (kg/kg)	Application rate (kg N/ha)
Bioganic	R 245,00	20	0,026	158
Talborne	R 180,00	5	0,074	158

Source: Gobozi, personal communication, 2017

With the aid of the values in Table 4.5, the following equation was used to determine the price of each commercial organic fertilizer treatment ("Cost(org)") that was required to meet a nitrogen demand of 158 kg/ha for a hectare of land:

$$\text{Cost(org)} = \frac{\text{cost of fertilizer}}{\text{mass of fertilizer (kg)}} \times \frac{158\text{kg/ha}}{\text{nitrogen content (kg/kg)}}$$

4.7. Scenarios

As defined earlier in this chapter, scenarios are used to explore the possible effects of including variations in, and adjustments to, a model. The subsections to follow describe the scenarios that were simulated for each treatment in the budget models.

4.7.1. Estimated costs where inputs were donated

In this study, some of the inputs in the treatments being assessed were either readily available or donated by a third party for the purpose of research. Some of the fertilizer costs associated with these treatments were recorded as zero. However under business circumstances these inputs would have to be purchased by the farmer who is using them regularly.

For the purpose of this scenario the only treatment which had an ingredient that was provided freely was the composted waste with biochar applied at 10m^3 per ha. The biochar that was used was available free of charge from the department of soil science at the University of Stellenbosch. However in order to test the relative cost of including biochar in the treatment, the average cost of biochar had to be obtained. Jirka and

Tomlinson (2014) reported that the average selling price of biochar from a list of different countries across five continents was 2.65 USD per kilogram of pure biochar (approximately ZAR 34.37 per kilogram based on the exchange rate in 2017). The composition of biochar for this treatment was 20%by mass; hence 2000kg of pure biochar was the application rate for this treatment, per hectare. The relative cost of biochar for this treatment was therefore the product of the cost per kilogram in Rands and the biochar application rate of 2000kg per hectare. The scenario where the cost of biochar was included in the cost of fertilizer was also simulated for the scenarios where the broccoli grown from using this treatment was sold at premium.

4.7.2. Premiums on organic products

As mentioned earlier the premiums that were assessed included a minimum and maximum percentage. The motivation behind including a premium was to determine the financial potential of an organic production system. This organic system is compared against a conventional counterpart after the premium on the original selling price was included. The fact that the selling price for this producer is close to that of the retailers indicates that he sells at a premium. Normally there would be a margin between the farm level price and retail price. The minimum premium that was used was 20% whereas the maximum was 40%. These correspond to an Indian premium range mentioned by Ramesh et al. (2010). The following equations were used to determine the revenues for both organic broccoli and green bean systems after the addition of premiums:

$$20\%\ \text{Premium} = (\text{R}35.00 \times 0.20) + \text{R}35.00$$

$$40\%\ \text{Premium} = (\text{R}35.00 \times 0.40) + \text{R}35.00$$

Upon inclusion of the premiums, it had to be borne in mind that the consumer needed reassurance that the organic product they were purchasing was indeed organic. Therefore the penalty of including the annual cost of obtaining certification was included wherever a premium was charged for an organic product. The cost of certification was determined by contacting an Ecocert certification agent to whom the farm was described. The quotation was made based on the assumption that the farm on which this research was performed met all the prerequisites listed in the Ecocert certification standard to obtain the certified organic label (Smith, personal communication, 2017).

4.7.3. Increase in hourly wages

It was mentioned in Chapter 2 that the government of South Africa intend on implementing a national minimum wage of ZAR 20.00 an hour in 2018. The downstream effect on crop production would be a higher cost for farm labour. This is specifically noteworthy for organic agriculture. In order to quantify this effect in financial terms a scenario was run whereby the hourly wage for seasonal labour was changed from ZAR 14.25 to ZAR 20.00. The scenario was set only for the organic treatment which had the highest and most positive gross margin, given that the seasonal cost of labour for all treatments (within the respective enterprise) was uniform.

The hourly wage of ZAR 14.25 for broccoli was used to calculate the original cost of seasonal labour so conversion was relatively straightforward. However, by the time the green bean enterprise was incepted the farmer had employed a labourer for ZAR 750.00 per week to do all farm work. In order to determine the weekly rate under the scenario of a higher wage, the ratio between the existing weekly and hourly wage of ZAR 14.25 was determined and used as multiplier for the new hourly wage of ZAR 20.00. The following equation was used:

$$\text{New weekly wage after increase} = \frac{\text{R750.00}}{\text{R14.25}} \times \text{R20.00}$$

4.8. Conclusions

The purpose of this chapter was to provide the details of the research project. The budget models constructed in this research were built on scientific data obtained directly from an ongoing research project piloted by a soil scientist. The study was performed on two crops; broccoli in the winter of 2016 and green beans in the summer of 2017 respectively. Five organic treatments and one inorganic amendment were assessed for each crop. One organic treatment was the control.

From the input costs as well as the hypothetical income obtained from the yield, partial and enterprise budget models were constructed whereby the gross margins were determined. Scenarios were created for the purpose of simulating realistic possibilities and the potential financial outcomes. Included among the scenarios were the addition premiums and an organic certification quote wherever an organic treatment was used. The average cost of biochar also included where composted waste and biochar was the treatment. Another scenario measured the effect on the GM of raising the hourly wage.

Chapter 5 describes and compares the outcomes of the simulated budget models with respect to each cropping system and treatment. The histograms used help to compare each treatment's gross margin with respect to the scenario being assessed.

Chapter 5 : Financial implications of organic and conventional fertilization

5.1. Introduction

The main aim of this research project is to assess the financial implications of various forms of organic fertilization in a smallholder vegetable production system. Chapter 4 commenced with a physical description of the farm near Raithby followed by a description of the biophysical study that was carried out. Both of the previously mentioned steps were necessary to contextualise the financial analyses that were described for this specific study. A detailed description of the types of budget models used as well as the respective budgetary inputs was also provided.

This chapter includes a presentation of the findings. The output data resulting from the inputs and methods described in Chapter 4 are described and discussed in detail. More specifically the gross margins are analysed for each of the enterprises (broccoli and green beans).

5.2. Gross margin analysis: Broccoli

5.2.1. Control treatment

Table 5.1: Budget models where no treatment was used as a soil amendment (control) under different scenarios for price premiums (0%, 20%, and 40%)

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 166 973	R 200 368	R 233 763
Directly allocatable variable costs			
Seedling	R 66 667	R 66 667	R 66 667
Pesticide (organic)	R 664	R 664	R 664
Seasonal labour	R 71 250	R 71 250	R 71 250
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	**R 28 393**	**R 42 977**	**R 76 372**

Source: Own analysis

The control treatment, as discussed in Chapter 4 excluded the use of a fertilizer. The gross margins for the control treatment are summarized in Table 5.1. As shown in Table 5.1, the control treatment for broccoli had a positive GM in all three scenarios; this indicates that the GVP is higher than the costs. The highest value for the gross margin was observed when the broccoli was sold at a premium of 40% (ZAR 76,372) whereas the lowest gross margin (ZAR 28,393) was observed when zero premiums was added on the product being. This was the case for all partial budgets built where the broccoli enterprise included an organic treatment. The two highest contributors towards costs were seasonal labour (ZAR 71,250) and seedling (ZAR 66,667) costs respectively.

5.2.2. Composted waste and 20% biochar treatment

Table 5.2: Gross Margins where composted waste and 20% biochar was used as a soil amendment under different scenarios for price premiums (0%, 20%, and 40%)

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 189 502	R 227 402	R 265 302
Directly allocatable variable costs			
Seedling	R 66 667	R 66 667	R 66 667
Pesticide (organic)	R 664	R 664	R 664
Seasonal labour	R 71 250	R 71 250	R 71 250
Composted biochar (20%)	R 10 556	R 10 556	R 10 556
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	**R 40 365**	**R 59 456**	**R 97 356**

Source: Own analysis

The gross margins for the composted waste and biochar (20%) treatment are summarized in Table 5.2. In Table 5.2, it can be observed that again that all three gross margins were positive and increased with respect to the premium added. Again, the two highest contributors towards costs were seasonal labour (ZAR 71,250) and seedling (ZAR 66,667) costs respectively. The cost of composted waste and biochar (ZAR 10,556) excluded the biochar expense. Another budget was compiled under the scenario where the farmer had to hypothetically purchase biochar of his own and is presented in Table 5.3.

Table 5.3: Gross margins where composted waste and biochar was used as a soil amendment under different scenarios for price premiums (0%, 20%, and 40%). These models factor in the average cost of biochar

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 189 502	R 227 402	R 265 302
Directly allocatable variable costs			
Seedling	R 66 667	R 66 667	R 66 667
Pesticide (organic)	R 664.00	R 664	R 664
Seasonal labour	R 71 250	R 71 250	R 71 250
Composted biochar (20%)	R 79 496	R 79 496	R 79 496
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	**R -28 575**	**R -9 484**	**R 28 416**

Source: Own analysis

The cost of biochar under these circumstances was ZAR 68,940; This value was obtained by determining the product of average selling price of biochar (ZAR 34.94 per kg) (Jirka & Tomlinson, 2014) and the relative mass used for the trial (2000kg) as was described in section 3.8.2.4. In this scenario it is evident that the cost of biochar significantly influenced the financial outcome. At zero and 20% premiums the GM values were negative (-ZAR 28,575 and - ZAR 9,484 respectively), whereas previously (when biochar costs were omitted from the budget) the values were positive (ZAR 40,365 and ZAR 59,456 respectively). Although there was a positive value for the GM at 40% premium (ZAR 28,416), when compared to the previous scenario (ZAR 97,356), the value was significantly lower regardless. Furthermore, factoring in the cost of biochar had the effect of propelling the fertilizer cost to being the highest (ZAR 79,496) of all the costs in the budgets represented in Table 5.3.

5.2.3. Composted waste treatment applied at 10t/ha

Table 5.4: Gross margins where composted waste applied at 10t/ha was used as a soil amendment under different scenarios for price premiums (0%, 20%, and 40%)

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 269 714	R 323 657	R 377 599
Directly allocatable variable costs			
Seedling	R 66 667	R 66 667	R 66 667
Pesticide (organic)	R 664	R 664	R 664
Seasonal labour	R 71 250	R 71 250	R 71 250
Composted waste	R 19 792	R 19 792	R 19 792
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	**R 111 342**	**R 146 474**	**R 200 417**

Source: Own analysis

The gross margins for the composted waste treatment applied at 10t/ha are summarized in Table 5.4. In the case where the compost was manufactured by the soil scientist and subsequently applied to the soil at a rate of 10t/ha as can be seen in Table 5.4, the gross margins were positive and increased with the premium respectively. The highest costs in the budget were the cost of seasonal labour (ZAR 71,250) and seedlings (ZAR 66,667) respectively.

5.2.4. Composted waste treatment applied at 22t/ha

Table 5.5: Gross margins where composted waste applied at 22t/ha was used as a soil amendment under different scenarios for price premiums (0%, 20%, and 40%)

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 221 620	R 265 944	R 310 269
Directly allocatable variable costs			
Seedling	R 66 667	R 66 667	R 66 667
Pesticide (organic)	R 664	R 664	R 664
Seasonal labour	R 71 250	R 71 250	R 71 250
Composted waste	R 43 542	R 43 542	R 43 542
Ecocert annual certification		R 18 810	R 18 810
Gross Margin	**R 39 498**	**R 65 012**	**R 109 336**

Source: Own analysis

The gross margins for the composted waste treatment applied at 22t/ha are summarized in Table 5.5. As was found in the previous treatment (where less than half the amount of the same compost was applied) Table 5.5 shows that the same gross margin trend (i.e. increased with the premium) was also observed for the composted waste treatment applied at 22t/ha. All the gross margin values were positive. Again it can be seen that the two highest budgetary costs were the cost of seasonal labour (ZAR 71,250) and seedlings (ZAR 66,667) respectively.

5.2.5. Commercial compost treatment (Reliance ®)

Table 5.6: Gross margins where Reliance® commercial compost was used as a soil amendment under different scenarios for price premiums (0%, 20%, and 40%)

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 209 666	R 251 599	R 293 532
Directly allocatable variable costs			
Seedling	R 66 667	R 66 667	R 66 667
Pesticide (organic)	R 664	R 664	R 664
Seasonal labour	R 71 250	R 71 250	R 71 250
Commercial compost	R 26 667	R 26 667	R 26 667
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	**R 44 418**	**R 67 541**	**R 109 474**

Source: Own analysis

The gross margins for the Reliance® compost treatment applied are summarized in Table 5.6. It can be seen in Table 5.6 above that all three gross margins were positive and increased with respect to the premium added. The two highest costs observed remained to be seasonal labour (ZAR 71,250) and seedling (ZAR 66,667) costs.

5.2.6. Inorganic fertilizer plan by Yara

The gross margins for the Yara inorganic fertilizer treatment applied are summarized in Table 5.7. The price premium assessment is excluded from this treatment. It is only applicable to all other treatments that qualify as "organic".

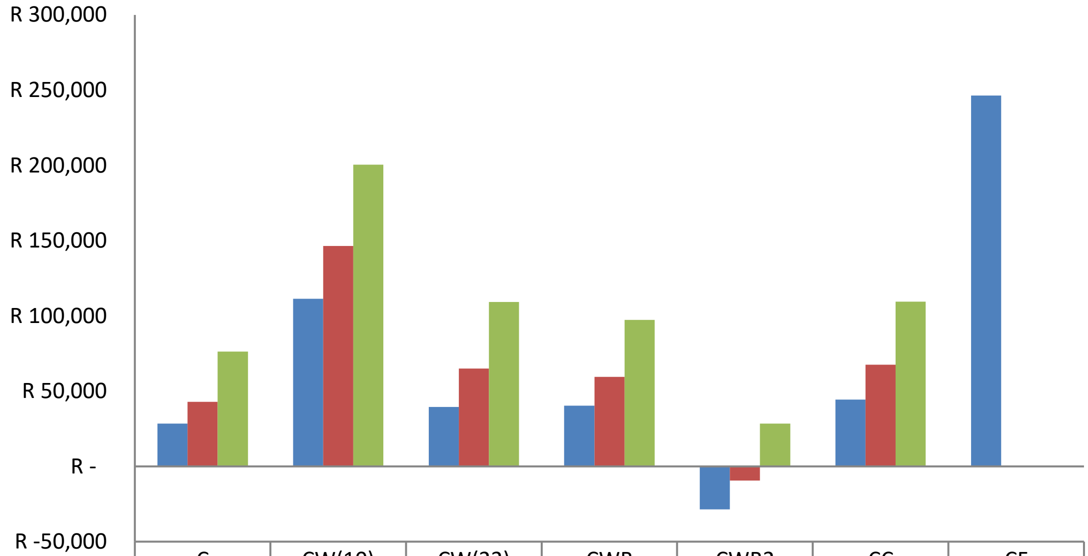
Table 5.7: Gross margins where Yara inorganic chemical fertilizer program was used as a soil amendment

Income (GPV)	
	R 394 396
Directly allocatable variable costs	
Seedling	R 66 667
Pesticide (organic)	R 664
Seasonal labour	R 71 250
Chemical fertilizer plan (Yara)	R 9 333
Gross Margin	**R 246 482**

Source: Own analysis

With regards to the inorganic chemical fertilizer the GM (ZAR 246,482) was observed to be a positive value as seen in Table 5.7. However the two highest costs remain to be the cost of seasonal labour (ZAR 71,250) as well as the cost of seedlings (ZAR 66,667).

5.3. Comparison of gross margins and budgets for broccoli production



	C	CW(10)	CW(22)	CWB	CWB2	CC	CF
0% Premium	R 28,393	R 111,342	R 39,498	R 40,365	R -28,575	R 44,418	R 246,482
20% Premium	R 42,977	R 146,474	R 65,012	R 59,456	R -9,484	R 67,541	R -
40% Premium	R 76,372	R 200,417	R 109,336	R 97,356	R 28,416	R 109,474	R -

Figure 5.1: The gross margins of each treatment applied in the broccoli production systems.

(Treatments: C= Control; CW(10)= Composted waste 10t/ha; CW(22)= Composted waste 22t/ha; CWB= Composted waste with biochar; CWB2= Composted waste with biochar incl. average cost of biochar; CC= Commercial compost from Reliance®; CF= Inorganic chemical fertilizer by Yara.):

Source: Own analysis

A comparison of the gross margins across the different treatments on broccoli was made and is shown in Figure 5.1. From the graph it is relatively easier to observe how each individual treatment performed with respect to the others.

From the aforementioned data it can be seen that of all the treatments in the broccoli production system, the inorganic fertilizer returned the highest gross margin (ZAR 246,482) despite not having a premium added on to the selling price. The cost of fertilizer for the aforementioned treatment was also the lowest of all treatments that had a cost greater than zero (ZAR 9,333). Furthermore the GVP value for the conventionally produced broccoli ranked the highest out of all six treatments (ZAR 394,396). Either of the aforementioned observations may serve as an explanation as to why the GM was highest when the Yara fertilizer program was adopted.

Commencing with the GM values that were produced in the absence of a premium selling price (0% Premium) it is evident that the chemical fertilizer treatment had the highest GM value out of all the treatments assessed. When considering only the organic treatments that were applied under these conditions the highest GM yielding treatment was the composted waste treatment applied at 10t/Ha (ZAR 111,342) followed by the commercial compost manufactured by Reliance® (ZAR 44,418). The GM of the composted waste with biochar (ZAR 40,365) treatment ranked third highest whereas the composted waste treatment applied at 22t/Ha (39,498 ZAR) was the fourth and had a value which was less than half of that of the composted waste treatment applied at 10t/Ha.

When regarding the organic amendments, the composted waste treatment applied at 10t/ha produced the highest gross margins for all three scenarios. Even when a premium of 40% was added to the selling price, the GM (ZAR 200,417) was still less than that of conventional broccoli. Although the cost of composted waste (ZAR 19,792) was budgeted to cost more than 10 000 ZAR than Yara's fertilizer (ZAR 9,333), the most limiting factor lay rather in the difference between the respective revenues generated at zero premium. This is directly linked to crop performance and yield.

The scenarios that were tested assumed that all vegetable sales were made directly by the farmer. In reality however there is a postharvest supply chain that exists from the farm to the consumer's fork, where the farmer has no control. Value added to any produce during the postharvest, pre-shelf phases will therefore be charged to the consumer. The money generated by this phase in the supply chain typically will not benefit the farmer. In a fragmented supply chain where a retailer sells a vegetable product at R35/kg, only a fraction of the money makes its way to the farmer's pocket. In other words the farmer stands to earn more money when he or she sells the final product themselves.

When observing the values for the composted waste with biochar (whereby the estimated cost of the biochar component is included in the budget) it is evident that the cost of biochar alone can cause the emergence of a negative GM. This was indeed true for the budgets that had zero (-ZAR 28,575) and 20% (-ZAR 9,484) premium adhered to the selling price respectively. When the average and relative cost of biochar was factored into the cost of the compost treatment Figure 5.1 illustrates that the biochar produced the lowest GM values of all the treatments (including the control).

Lastly, when the individual costs of each budget model are evaluated, it can be seen that the highest input costs are seedling costs (ZAR 66,667) and seasonal labour (ZAR 71,250). The only exception to this trend is seen in Table 5.3 where the cost of biochar is factored into the cost of compost which amounted to ZAR 79,496.

5.4. Gross marginal effect of minimum wage increase on organic broccoli production

The gross margins for the organic broccoli treatment with the highest GM (composted waste treatment applied at 10t/ha) are summarized in Table 5.8. In this scenario the hourly wage was raised from ZAR 14.25 to ZAR 20.00.

Table 5.8: Effect of increased hourly wage to ZAR 20.00 on seasonal labour expense and gross margin where a treatment of composted waste was applied at 10t/ha

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 269 714	R 323 657	R 377 599
Directly allocatable variable costs			
Seedling	R 66 667	R 66 667	R 66 667
Pesticide (organic)	R 664	R 664	R 664
Seasonal labour	R 83 571	R 83 571	R 83 571
Composted waste	R 27 778	R 27 778	R 27 778
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	**R 91 034**	**R 126 167**	**R 180 110**

Source: Own analysis

In the scenario where wages increased from ZAR 14.25 to ZAR 20.00 per hour it can be seen from the budget in Table 5.8 that the gross margin was positive under all premiums. However, when considering the same budget where hourly wages were ZAR 14.25 (i.e. Table 5.4), it is evident that the gross margin measured for all premiums was less than when hourly wages were ZAR 20.00 (i.e. Table 5.8). The rise in wages meant that a seasonal labour cost of ZAR 71,250 would increase to a value of ZAR 83,571. The cost of fertilizer also increased to ZAR 27,778 as the cost of manufacturing was raised with the wages. The loss in GM experienced through higher wages was ZAR 20,308 for all premiums.

5.5. Gross margin analysis: green (bush) beans

5.5.1. Control Treatment

The control treatment for green beans, as with broccoli production, excluded the use of a fertilizer. The gross margins for the control treatment are summarized in Table 5.9.

Table 5.9: Gross margins where no treatment was used as a soil amendment (control) under different scenarios for price premiums (0%, 20%, and 40%)

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 200 833	R 241 000	R 281 167
Directly allocatable variable costs			
Seeds (Stark 2000)	R 45 052	R 45 052	R 45 052
Seasonal labour	R 78 750	R 78 750	R 78 750
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	R 77 031	R 98 388	R 138 554

Source: Own analysis

As seen in Table 5.9, the control treatment for green beans had a positive GM in all three scenarios; hence the enterprises GVP was greater than the costs under all three conditions. The highest value for the gross margin was observed when the beans were sold at a premium of 40% (ZAR 138,554). The lowest gross margin was observed when zero premiums (ZAR 77,031) were added on the product being sold. Similarly for all other budgets where an organic treatment was used, the gross margin increased with magnitude of the premium. The highest costs in this budget were for seasonal labour (ZAR 78,750) and seeds (ZAR 45,052).

5.5.2. Talborne organic fertilizer treatment (high nitrogen)

Table 5.10: Gross margins where Talborne organic fertilizer treatment (high nitrogen) was used as the soil amendment under different scenarios for price premiums (0%, 20%, and 40%)

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 221 389	R 265 667	R 309 944
Directly allocatable variable costs			
Seeds (Stark 2000) Seasonal labour Fertilizer (Talborne) Ecocert annual certification	R 45 052 R 78 750 R 76 865 R -	R 45 052 R 78 750 R 76 865 R 18 810	R 45 052 R 78 750 R 76 865 R 18 810
Gross Margin	**R 20 722**	**R 46 189**	**R 90 467**

Source: Own analysis

The gross margins for the Talborne organic fertilizer treatment are summarized in Table 5.10. In the case where Talborne organic fertilizer was used as the soil amendment (Table 5.10) a positive gross margin was produced where the green beans were sold at zero premium (ZAR 20,722). The same observation was made when premiums of 20% (ZAR 46,189) and 40% (ZAR 91,467) respectively were added to the selling price of beans. The highest costs in this budget were for seasonal labour (ZAR 78,750) and fertilizer (ZAR 76,865).

5.5.3. Bioganic organic fertilizer treatment (low nitrogen)

Table 5.11: Gross margins where Bioganic organic fertilizer treatment (low nitrogen) was used as the soil amendment under different scenarios for price premiums (0%, 20%, and 40%).

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 191 11	R 229 333	R 267 556
Directly allocatable variable costs			
Seeds (Stark 2000)	R 45 052	R 45 052	R 45 052
Seasonal labour	R 78 750	R 78 750	R 78 750
Fertilizer (Bioganic)	R 74 442	R 74 442	R 74 442
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	**R -7 134**	**R 12 279**	**R 50 501**

Source: Own analysis

The gross margins for the Bioganic organic fertilizer treatment are summarized in Table 5.11. A negative gross margin was produced (-ZAR 7134) at zero premiums. However in the case where a 20% (ZAR 12,279) and 40% (ZAR 50,501) premium was added, respectively, to the selling price, the GM was positive. The highest costs in this budget were for seasonal labour (ZAR 78,750) and fertilizer (ZAR 74,442).

5.5.4. Farmer's compost treatment

Table 5.12: Gross margins where the farmer's compost was used as a soil amendment under different scenarios for price premiums (0%, 20%, and 40%).

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 275 278	R 330 333	R 385 389
Directly allocatable variable costs			
Seeds (Stark 2000)	R 45 052	R 45 052	R 45 052
Seasonal labour	R 78 750	R 78 750	R 78 750
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	**R 151 475**	**R 187 721**	**R 242 776**

Source: Own analysis

The gross margins for the farmer's compost organic treatment are summarized in Table 5.12. Where the farmer's compost was applied (Table 5.12) as a treatment, three positive values for the gross margin at zero (ZAR 151,475), 20% (ZAR 187,721) and 40% (ZAR 242,776) premiums were yielded, respectively. The magnitude of the gross margin increased with the magnitude of the premium on the selling price of beans. A price for the compost is absent as the treatment merely consisted of grass clippings and the organic material from the floor of the chicken pen on the property. The highest costs in this budget were for seasonal labour (ZAR 78,750) and seeds (ZAR 45,052).

5.5.5. Stellenbosch University commercial compost

Table 5.13: Gross margins where Stellenbosch University commercial compost was used as the soil amendment under different scenarios for price premiums (0%, 20% and 40%).

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 215 556	R 258 667	R 301 778
Directly allocatable variable costs			
Seeds (Stark 2000)	R 45 052	R 45 052	R 45 052
Seasonal labour	R 78 750	R 78 750	R 78 750
Commercial compost	R 17 348	R 17 348	R 17 348
Ecocert annual certification	R -	R 18 810	R 18 810
Gross Margin	**R 74 405**	**R 98 707**	**R 141 818**

Source: Own analysis

The gross margins for the Stellenbosch University compost treatment are summarized in Table 5.13. As seen in Table 5.13, the Stellenbosch University commercial compost treatment for green beans had a positive GM for all three scenarios. The highest costs in this budget were for seasonal labour (ZAR 78,750) and seeds (ZAR 45,052).

5.5.6. Inorganic (chemical) fertilizer plan by Yara

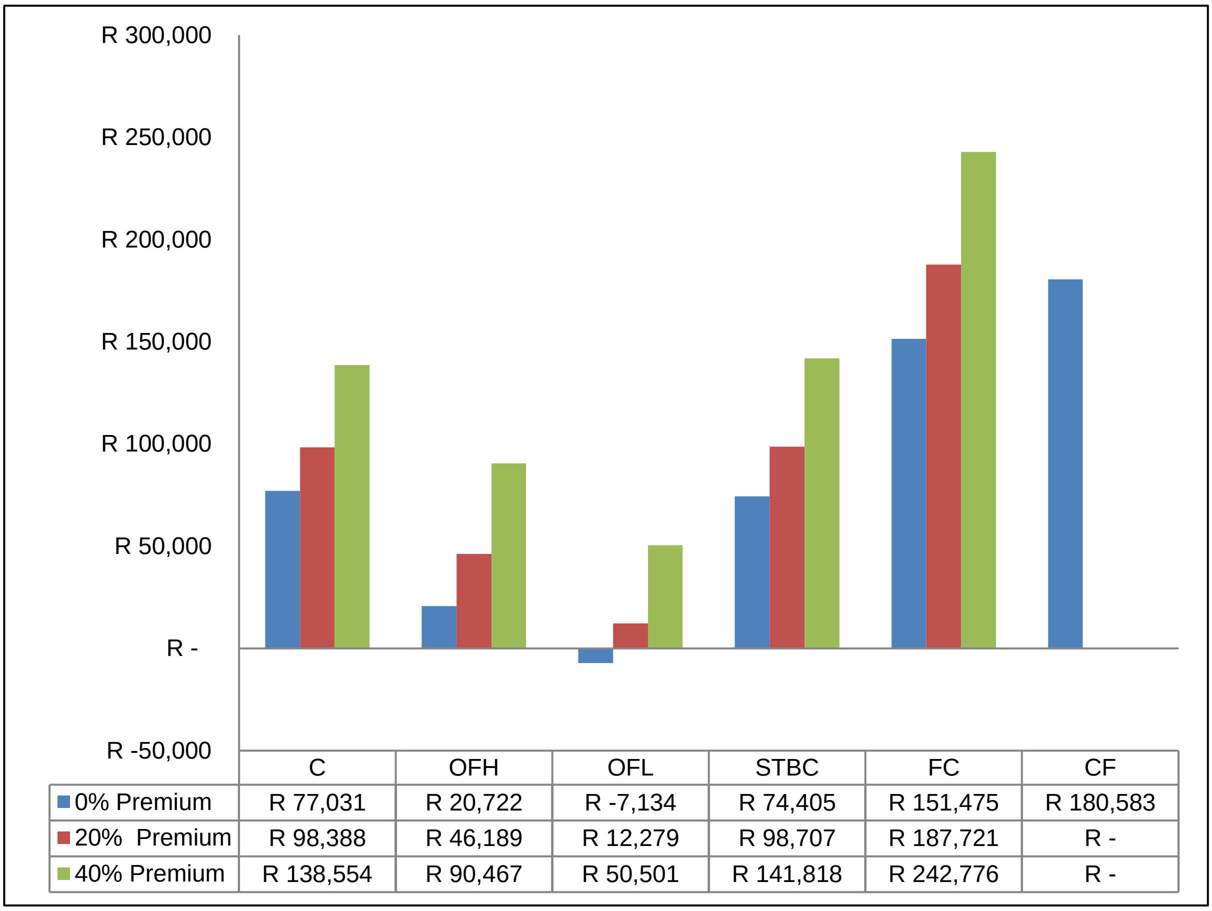
Table 5.14: Gross margins where Yara inorganic chemical fertilizer program was used as the soil amendment under different scenarios for price premiums (0%, 20%, and 40%).

Income (GPV)	
	R 312 778
Directly allocatable variable costs	
Seeds (Stark 2000) Seasonal labour Fertilizer (Yara programme)	R 45 052 R 78 750 R 8 392
Gross Margin	**R 180 583**

Source: Own analysis

The gross margin (ZAR 180,589) for the budget where the Yara fertilizer program was used as a treatment is summarised in Table 5.14. The GM was positive, thus indicative of higher revenues than cost. The highest costs in this budget were for seasonal labour (ZAR 78,750) and seeds (ZAR 45,052).

5.5.7. Comparison of gross margins for green (bush) beans production



	C	OFH	OFL	STBC	FC	CF
0% Premium	R 77,031	R 20,722	R -7,134	R 74,405	R 151,475	R 180,583
20% Premium	R 98,388	R 46,189	R 12,279	R 98,707	R 187,721	R -
40% Premium	R 138,554	R 90,467	R 50,501	R 141,818	R 242,776	R -

Figure 5.2: Comparison the gross margins (R) for each treatment applied in the green beans production systems.

(Treatments: C= Control; OFH= Talborne organic fertilizer (high N); OFL= Bioganic organic fertilizer (low N); STBC= Stellenbosch University compost; FC= Farmer's Compost; CF= Inorganic chemical fertilizer by Yara.):

Source: Own analysis

A comparison of the gross margins across the different treatments on green beans was made and is shown in Figure 5.2.

When zero premiums were added onto the selling price of green beans, it is clear that the GM was most positive when the inorganic chemical fertilizer was used as the treatment (ZAR 180,583). Of the organic treatments, the GM was highest and positive when the farmer's compost (ZAR 151,475) was used; however this value still fell short of the chemical fertilizer's GM. The control (ZAR 77,031), Stellenbosch University compost (ZAR 74,405) and Talborne (ZAR 20,722) treatments were also all positive in comparison to the Bioganic organic fertilizer treatment. That treatment had relatively lower nitrogen mass per kilogram and produced the lowest and only negative GM value of all the treatments (-ZAR 7,134).

The first observation made amongst the organic treatments when a 20% premium was put on the selling price of green beans, was that yet again the farmers compost treatment yielded the most positive GM value (ZAR 187,721). This was the only organic treatment to surpass the GM of the Yara inorganic fertilizer treatment (ZAR 180,583) in this scenario. The GM's of the control and Stellenbosch University compost treatments increased to again positive values of similar magnitude (ZAR 98,388 and ZAR 98,707). The lowest but now positive GM value was again observed for the Bioganic organic fertilizer treatment (ZAR 12,279). The Talborne treatment yielded the second lowest GM value (ZAR 46,189).

When a 40% premium was added onto the selling price of green beans for all organic treatments, the farmer's compost treatment was the only case where the GM (ZAR 242,776) was higher than that of the chemical fertilizer treatment. All other organic treatments rendered lesser (but yet all positive) GM values compared to the chemical fertilizer treatment.

When one evaluates and compare each cost of the budgets modelled several observations can be made. The first observation is that the seed cost (ZAR 45,052) for green beans was actually less than that of green beans. However it was still amongst the top two expenses for four of six the treatments. Secondly, the commercial organic fertilizers Talborne (ZAR 76,865) and Bioganic (ZAR 74,442) were the most and second most expensive amendments respectively. Due the availability of free farmer's compost, it was the cheapest treatment. Seasonal labour (ZAR 78,750) was amongst the top two expenses in all scenarios.

5.5.8. Gross marginal effect of minimum wage increase on organic green (bush) production

The gross margins for the organic bush beans treatment with the highest GM (farmer's compost) are summarized in Table 5.15. The hourly wage, in this scenario, was raised from ZAR 14.25 to ZAR 20.00.

Table 5.15: Effect of increased hourly wage to ZAR 20.00 on seasonal labour expense and gross margin the farmer's compost treatment was applied.

Income (GPV)	**0% Premium**	**20% Premium**	**40% Premium**
	R 275 278	R 330 333	R 385 389
Directly allocatable variable costs			
Seeds (Stark 2000) Seasonal labour Ecocert annual certification	R 45 052 R 110 526 R -	R 45 052 R 110 526 R 18 810	R 45 052 R 110 526 R 18 810
Gross Margin	**R 119 699**	**R 155 945**	**R 211 000**

Source: Own analysis

In the scenario where wages increased from ZAR 14.25 to ZAR 20.00 per hour it can be seen from Table 5.15 that the gross margin was positive under all premiums. However when considering the same budget where hourly wages were ZAR 14.25 (i.e. Table 5.12) it is evident that the gross margin measured for all premiums was lesser when hourly wages were ZAR 20.00 (i.e. Table 5.15). The rise in hourly wages meant that a seasonal labour cost of ZAR 78,750 would accentuate to a value of ZAR 110,526. The difference therefore between the GMs (ZAR 31,776) (with respect to premiums) of Table 5.12 and Table 5.15 was the same as for the cost of seasonal labour.

5.6. Conclusions

This chapter commenced with the presentation and discussion of the budget models that were built upon the input data from the broccoli field trial. The highest GM was produced when the inorganic chemical treatment was used. This observation remained true despite the added premiums on the organic treatment broccoli selling prices. With premiums, composted waste applied at 10t/ha competed best against the inorganic fertilizer treatment. The highest costs observed for all treatments and scenarios were that of seasonal labour and seedlings. The only exemption was when the average cost of biochar was factored into the cost of compost.

The inorganic chemical fertilizer treatment on green beans produced the highest GM. This observation changed when 20% and 40%, premiums respectively, were added onto the selling price of organically treated green beans. For both scenarios the farmer’s compost treatment out-performed the chemical fertilizer treatment. In all budgets and scenarios the highest cost was mostly attributable to seeds, labour and organic fertilizers (namely Talborne and Bioganic) when used. The costs of organic fertilizers, Talborne and Bioganic, were the highest of all the treatments whereas the cost of farmer’s compost was the cheapest.

For both of the aforementioned enterprises the effect of raising the wage to ZAR 20.00 an hour was associated with a drop in the GM. Despite the drop both of the respective GMs remained positive.

Based on the evidence organic fertilizers yield lower GMs than inorganic fertilizers. The producer would need another incentive, either a premium price or a real ecological or social benefit. Both ecological and social benefits were discussed in Chapter 2. It could be well that these outweigh profits in the form of market security.

Chapter 6 : Conclusions, Summary and Recommendations

6.1. Conclusions

The planet is continuously accommodating a growing human population. This increases pressure on land and other natural resources. Furthermore the act of globalisation and the development of developing countries cause cultural shifts due to the improvement of people's purchasing power. This then affords people the option of buying food according to their own will. This demand not only creates pressure on the earth's resources but also applies pressure on the farming environment to produce more food more efficiently. This in turn can have unforeseen economic and social repercussions therefore.

Though lauded by several researchers, the long term sustainability of conventional agricultural methods have been widely questioned for their deleterious effect on the natural environment of the planet. Often there are negative social and economic externalities. These imperfections have caused some to deviate from the conventional approach to agriculture and adopt organic agricultural principles. The concept of organic farming encompasses a holistic approach to agricultural production systems, thus acknowledging interactions between sub-systems both on and off the production unit. However it is inaccurate to take for granted that an organic approach is inherently sustainable.

The global market for organic produce is growing. However, South Africa, relative to other nations such as Uganda, has less organic farmers; most of whom however, operate on a larger scale.

The sustainability of any agricultural system is determined by how economically feasible it is to manage, how socially acceptable and relevant it is to the stakeholders, and how damaging the system is to the environment. It is possible for any agricultural system to fall short on long term sustainability, should any of the abovementioned criteria for measuring sustainability be significantly limiting.

Evaluating the sustainability of any novel technology is necessary. This process helps to assess the technology's relevance and usefulness in the real world despite its degree of technical sophistication. Setting standards for sustainability versus unsustainability may be complex especially when defining specific thresholds.

The main aim of this research was to assess the implications of using various fertilizer options in vegetable production systems within the Stellenbosch area. In support of this aim, the research also aimed to asses the ecological and social contributions of organic farming to sustainability and determine the financial implications of converting from inorganic fertilizers to organic fertilizers.

A few benefits of converting to an organic fertilization plan in crop production can be beneficial in several ways. The use of compost can have the benefit of improving soil's water and elemental retention capacity. Socially it can be better for food safety to fertilize organically because organic food products are less likely to have chemical residuum than conventional products. Globally, the organic market is growing annualy. This, as well as the current exclusivity in the market can potentially incentivise prospective farmers to adopt organic priniciples.

Models can be useful in assessing the profitability and economic sustainability of an agricultural system. Budget models exploit the principles of accountancy and mathematics to effectively represent a perception of an existing system. Such models can have many uses when it comes to planning, managing and controlling the allocation of resources. They can also provide a forecast of the finances of a current system. All this is done by running various simulations of scenarios on a constructed model. A major benefit of budget models when simulating farm systems in a spreadsheet environment is that the components that determine ecological sustainability can be incorporated.

By employing enterprise and partial budgeting techniques it was possible to model the relative profitability of incorporating various organic versus inorganic fertilizers into crop production systems. This was achieved through measurement of the gross margins of six different treatments per enterprise namely broccoli and green beans. The scenario of higher price premiums (20% and 40%) on organic products made it possible to improve the gross margins of organic treatments, despite the additional cost of certification renewal. The scenario of higher wages however, negatively influenced the gross margins of the best performing organic treatments from each respective enterprise.

In the case where broccoli was the cultivated crop of choice the following main observations were made:

(i) Where inorganic fertilizer was the treatment, the highest gross margin was obtained. This remained true when premiums were added onto the broccoli selling prices for the organic treatments

(ii) The inorganic fertilizer program was therefore the most profitable of the six treatments

(iii) The organic treatment which competed best against the gross margin of the chemical fertilizer was the composted waste applied at 10t/ha

(iv) The relative performance of the composted waste improved as the premiums on the broccoli selling price increased

(v) The cost of seasonal labour and the cost of composted waste fertilizer applied at 10t/ha both increased with the wages and

(vi) The two highest input costs were for seedlings and seasonal labour (barring the biochar scenario).

Other observations for the broccoli enterprise include the drop in GM when the cost of biochar was factored into the fertilizer cost of production. The gross margin recorded was positive prior to the incorporation of the average cost of biochar. After the average price became factored in, the gross margin turned negative (under zero and 20% premiums)

Where green beans were the cultivated crop of choice the following main observations were made:

(i) The budget produced when inorganic chemical fertilizer was the treatment had the highest GM observed at zero premiums,

(ii) The budget where the farmers compost was used as the treatment produced the highest GM of all the organic treatments, and under all the scenarios,

(iii) When 20% and 40% premiums were added to the selling price of green beans the gross margins of the farmer's compost budgets surpassed that of the inorganic chemical fertilizer. No other organic treatment was able to replicate the same outcome,

(iv) This was true despite the additional cost of certification associated with selling at premium, and

(v) The cost of seasonal labour increased when the hourly wage was set to ZAR 20.00. The GM for the budget where the farmer's compost was the treatment remained positive.

The results from the financial analysis led to the following main conclusions:

- At zero premiums the chemical fertilizer program is more financially feasible than any organic fertilizer treatment.

- It is not financially viable to included biochar in the broccoli production system where it initially has to be purchased.

- It is financially feasible to farm with the farmer's compost when producing green beans. Obtaining an organic certification and selling the product at a 20% and 40% premium thereafter offers a greater GM. It is possible to improve the profitability of an organic production system by adding premiums.

- Increasing the hourly wage to ZAR 20.00 lowered the GM under all scenarios. The cost of fertilizer increased where composted waste was applied at 10t/ha; this was because the cost of making the fertilizer had increased with wages.

- For a producer to convert away from using inorganic fertilizers, an incentive needs to be in place. This could be a price premium, ecological benefit or social benefit such as secure market access.

The main aim of this project was to compare the profitability of growing and selling vegetables produced either organically or conventionally as a smallholder in South Africa. The methods adopted can be useful for comparing relative economic sustainability of using different fertilizer options. It was concluded that the budget models that were constructed from the secondary data obtained were successfully used to compare the relative profitability of using organic fertilizers as opposed to using fertilizers of inorganic origins. It was also possible to improve the profitability of organic produce by increasing the premiums on the selling price, despite having the penalty cost of obtaining an organic certificate.

6.2. Summary

The negative effects of using conventional agricultural practices have alarmed many individuals to place any related agricultural practices under high scrutiny. The threat of food insecurity due to population growth in the 1900’s was largely combatted with the development of green revolution technologies. Although initially met with some scepticism, it was deemed at the time by many as an answer to several agricultural problems. The technologies and philosophies of the green revolution became popular and conventional as the fruits of their adoption were plentiful. Many of the associated dangers of using such technologies however, were discreet then, and are more obvious today as research has revealed over time. Some technological solutions developed in the 1900’s have had, and still have, deleterious socio-economic and environmental side-effects. The methods and philosophies of conventional agriculture have been well perpetuated around the world because of their apparent success and efficiency during a period in time where farmers were pressurised substantially. The widespread adoption of conventional agricultural practices and principles would not have been achievable without the influence of policy, the threat of food insecurity due to over-population as well as their scientific soundness.

For these (amongst other) reasons the ideal principles of conventional agriculture are still very much employed. However since the flaws in conventional farming have been brought to light, the sustainability of its adoption has been queried. The aforementioned pressures still persist at present; overpopulation, food and resource insecurity. A popularised alternative to the conventional agriculture philosophy is the concept of organic agriculture. In organic farming the use of GMO's and agro-chemicals is strictly prohibited from the production process. When comparing the dossier of research and information available for conventional agriculture to that of organic, the latter suddenly appears to be a rudimental novelty.

From the negative health effects of overusing agro-chemicals, to the environmental effects of clearing rainforests for plantations, the list of reasons as to why the conventional mind-set cannot be the sole approach to narrowing the yield gap is vast. Bearing this in mind, and with billions of US dollars at risk as well as the livelihoods of many who depend on industries related to conventional agriculture, changing the course of agriculture can become a socio-political and economic disaster.

With all things said and done pressure is mounted on the farmers. Consumers are now more aware of the health and environmental risks associated with the use and ingestion of agro-chemicals. The demand for organic produce which is grown with less of such inputs is increasing. The growing middle class of developing countries sees these pressures amplified as they are able to demand and pay for food that is organic. The accompanied rise in meat consumption with wealth status places the arable land and resources demanded for animal husbandry in competition with crop production. With knowledge of the side-effects of persistent chemical use, legislation is also making it harder for farmers to export into foreign countries if they violate residue limits. The reality is that conventional farmers are now expected to produce the same amount or more, whilst using fewer inputs.

Determining whether or not organic principles are a sustainable substitute for conventional philosophies is determined by several intersecting factors. The sustainability of any agricultural practice will be assessed on its commitment and compliance towards limiting environment degradation and upholding socio-economic standards. This means that regardless of the approach, organic or conventional, it has to meet and maintain a pre-set standard whereby the environment is not severely degraded, it is socially acceptable and economically feasible. All three of the aforementioned criteria for evaluating the sustainability of a farming system have to be satisfied.

The organic industry's market value is rising, with North America leading the race and European countries closely following. Uganda has the second most organic producers on the African continent estimated at 190 000, most of whom are smallholders. South African organic farming is well below this figure most of which is large scale. Nonetheless the smallholder population in South Africa plays an important role in financing the livelihoods of more than four million people. Higher input costs would affect these farmers the most due to their smaller production scale. Reducing their reliance on inputs could mean that they become more resilient to socio-economic changes. The prospect of growing the South African organic food market through smallholders should not be overlooked and should be tested for its economic potential to the farmers themselves.

In this study the purpose was to determine and compare the economic sustainability, of running two crop production systems, both either organically or conventionally on a smallholding. This was achieved through the use of budget models and simulations of various scenarios. The models were used to forecast real world scenarios; where the outcomes of changes within different components of a farming system were assessed. Models are useful tools for represting and describing real world systems that cannot be directly observed or described. The types of budget models that were used throughout the research period were enterprise budgets and partial budgets.

The models were built upon data collected from a trial involving broccoli and green beans that were grown in the winter 2016 and summer 2017 respectively. The data included yields, hours of labour, seed or seedling costs, pesticide and fertilizer costs.

For the broccoli trial the treatments included a control (no fertilizer), composted waste applied at 10 t/ha and 22t/ha, composted waste applied with 20% biochar at 10t/ha, commercial compost manufactured by Reliance and a crop specific chemical fertilizer program designed, and made by Yara. Essentially there were five organic treatments and only one conventional treatment assessed in this research trial. Each fertilizer cost was calculated based on time spent on manufacturing and or retail value. The cost of manufacturing a fertilizer was considered as a fertilizer cost and not as a farm labour cost. Other input costs included the cost of seedlings, organic biocides and farm labour. The other costs were assumed constant. These include irrigation, tools and equipment and packing material.

The green bean trial also included a crop specific fertilizer program that was developed by Yara and 5 other organic treatments namely; the control (no fertilizer), Talbourne organic fertilizer (high N), Bioganic organic fertilizer (low N), Stellenbosch University compost and the farmer’s compost. In this case the cost of each fertilizer was calculated based on quantity and retail prices since each fertilizer had a commercial price attached. Other input costs included in the budgets were the seed costs as well as the cost of farm labour.

The effect of adding 20% and 40% premiums to the selling price of each enterprise was tested in the form of scenarios. This was done to quantify the effect that price premiums can have on improving the potential profitability of an organic operation. Premiums were only added wherever organic treatments were used (i.e. no inorganic chemical fertilizers by Yara). Associated with the added premium was the penalty cost of having to obtain an organic certification from Ecocert. For the broccoli enterprise the GM of composted waste treatment applied at 10t/ha competed best against that of the inorganic chemical fertilizer treatment. Although the positive GM of the organic treatment increased with the premiums it still remained less than that of the Yara treatment, even after the highest premium of 40% was added. As for the green beans enterprise, the addition of both premiums actually caused the GM to surpass that of the respective Yara chemical treatment. The only incident where this was observed was when the green beans were treated with the farmer’s compost.

Another scenario that was tested on the GM of the organic treatment with the highest GM value in each enterprise was the effect of increased wages. The justification behind this scenario was the fact that organic agriculture can be more demanding on labour than the conventional approach. Bearing this in mind the South African national minimum wage is expected to be implemented in May 2018 and could lead to a higher production cost for organic agriculture.

For the broccoli enterprise where composted waste applied at 10t/ha was the treatment, the GM was reduced but still positive under all premium scenarios when wages were increased from ZAR 14.25 to ZAR 20.00. The decline observed was due to the increased seasonal labour cost, as well as the raised cost of fertilizer because it was manually manufactured. The same observation due to the former was made in the green beans enterprise where the farmer’s compost was applied as the treatment.

Biochar was manufactured by a third party and received free of charge. Obtaining the total cost of making that biochar was impossible. Using any retail price was not an option, as biochar prices can vary substantially between manufacturers. Hence the average global cost of biochar was obtained and included in the cost of fertilizer, in order to run a scenario which assessed its potential effect on the gross margin. When the cost of biochar was factored into the fertilizer cost in the budget, the GM went from being positive under all premiums to being negative. This was true when zero and 20% premiums were added to the green bean selling price.

It must be borne in mind that the budgets as well as the results from the budget simulations take into account various assumptions. Hence other farmers wanting to replicate the model elsewhere will have to take into account and also meet the assumptions.

Whether or not the presence of price premiums can sustain the profitability of organic farming is unknown. It is also unknown whether or not consumers in the region would be willing to buy organic produce that is priced higher than the same item produced conventionally. If not then the socio-economic sustainability of producing such commodities is not fully satisfied. To wholly determine if such a systemic perturbation might or might not succeed, research would have to be extended to the consumers of the region. In this way the research could ascertain if local consumers are in fact willing buy organic food and if so what it is they're willing purchase (from the possibilities offered by the farmer) and whether or not they can afford to pay more for it.

6.3. Recommendations

Making recommendations to the farmer about what to grow and how to grow it is complex. The recommendations depend on numerous interacting factors such as availability of resources and capital, the farmer's aims, and the climate. Furthermore equal dependence will also rest on what the consumer target market is demanding. Nonetheless, the scopes of the recommendations in this study are solely based on the data from what was researched (i.e. the gross margins).

Regarding broccoli cultivation over winter in the Western Cape the recommended treatment to use in combination would be the inorganic chemical fertilizer program by Yara. However if the farmer was adamant on producing organically then the recommended fertilizer to supplement the crop is the composted waste treatment applied at 10t/ha. In order to minimise the GM difference between the aforementioned treatment and that of Yara, an added 40% premium onto the selling price of his organic produce is advised.

The recommended treatment to complement the summer production of green beans is again the inorganic fertilizer program by Yara. The recommended organic treatment to use in for organic production is the farmer's compost which is freely available. The farmer can also opt to be recognised for growing organically and obtain a certification whilst selling at a 20% premium. If the market's response remains the same then the farmer will earn more under these conditions than growing and selling the same crop conventionally. The same views are held when the premiums are 40%.

With the aid of premium scenarios it was possible to manipulate and improve the profitability of the organic treatments. The effects of higher prices on consumer preference however are unknown for this study. It would therefore be of use to complete a study where this is measured scientifically.

The project was carried out for only one growing season per enterprise. The same trial could be carried out over more seasons to determine whether the treatments effects on the crop performance and soil characteristics are cumulative or continuous. Furthermore, this research can be used in collaboration with similar studies to build a database which prospective farmers in the Raithby and Stellenbosch region can access for insight.

Although the water supply during this study was not limiting, the Western Cape experienced severe water shortages at the time of writing. Cognizance should be given to the financial implications of water scarcity by farmers and researchers who want to apply the recommendations commercially and (or) academically.

It should also be borne in mind that this study was a comparative study where different methods of producing a commodity were weighed against one another. Hence the recommended treatments in this case may not necessarily be the best of all existing possibilities since only six were analysed per crop. Therefore, even the recommended methods are open to criticism and future research could incorporate more treatments. Research where more treatments are included is suggested.

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Personal Communications (Direct, telephonic or written communications)

Gobozi, T, K, S. 2017. Personal communication. Co-researcher. Stellenbosch University

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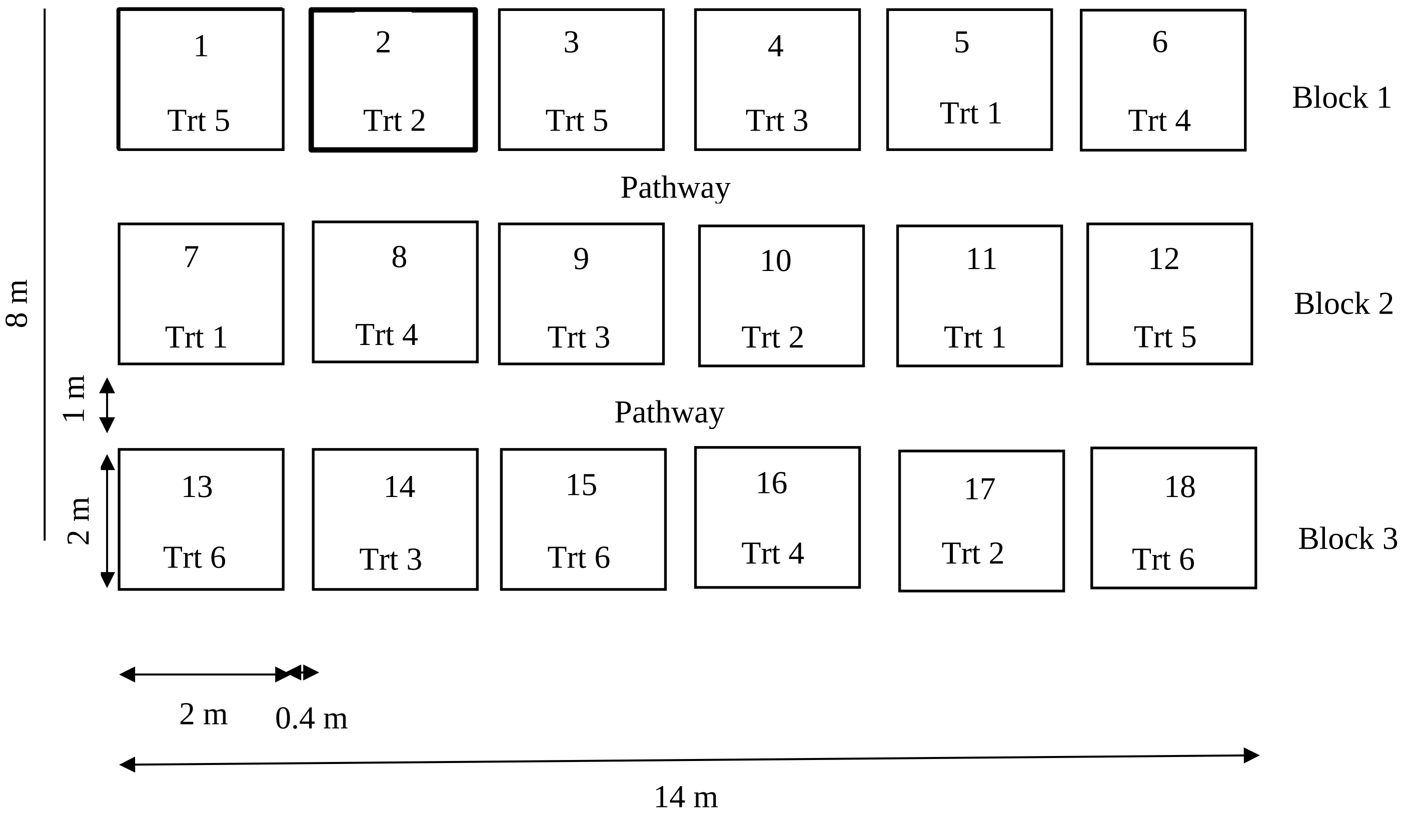
Annexures

Annexure A: Map of farm and experimental site from Google

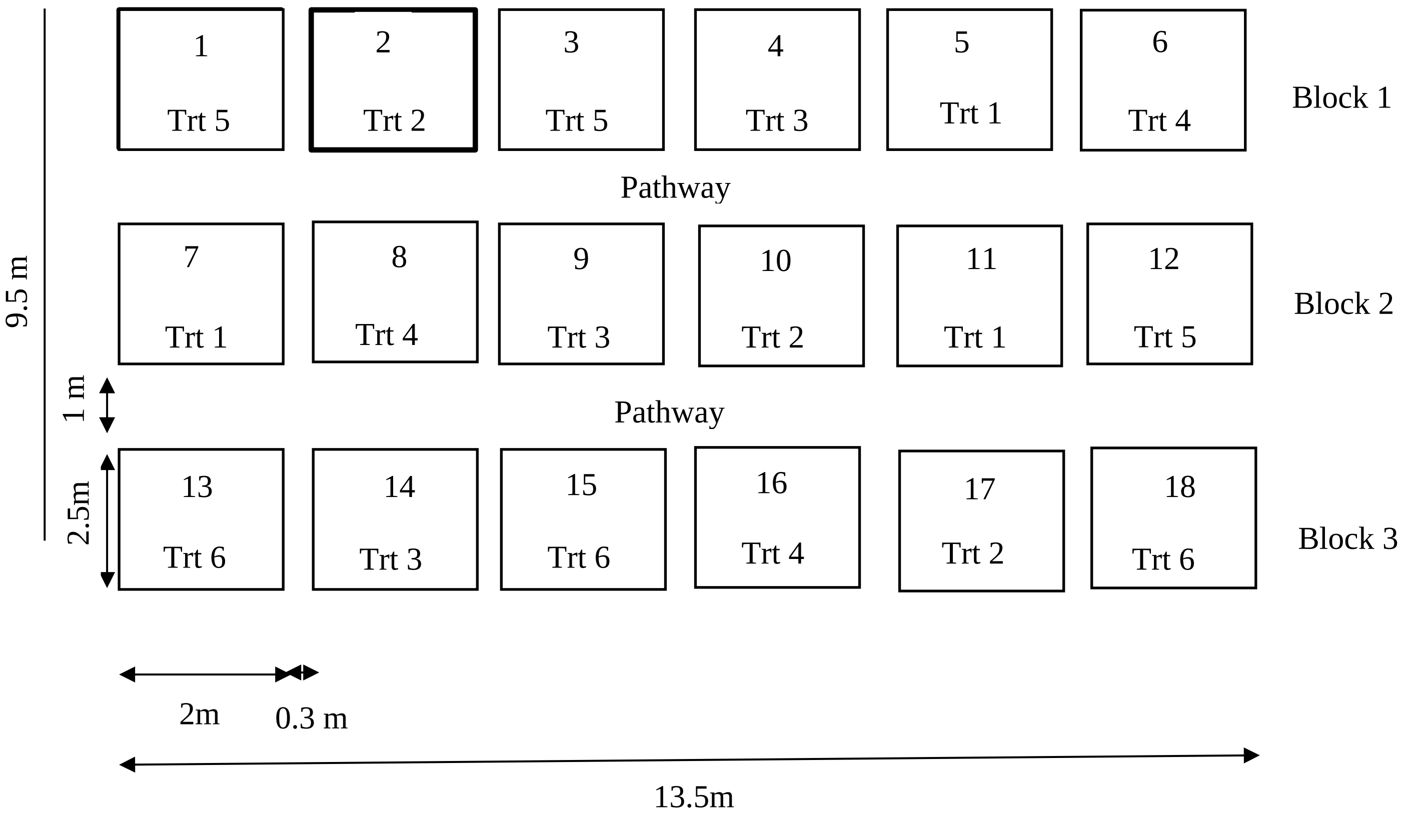
Source: Adapted from Google Maps, 2017.

Annexure B: Broccoli field trial design



Source: Gobozi, 2016.

Annexure C: Green bean field trial design



Source: Gobozi, 2016.