Small Scale Farmers Utilization and Perceptions of Bambara Groundnut Production in South Africa: A Case Study in a Semi-Arid Region of Limpopo

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Abstract

World food security will be one of the greatest global challenges in the 21st century and utilisation of an increased range of food crops is generally regarded as being vital to meeting this challenge, including the use of legumes. Bambara groundnut (*Vigna subterranea*) is an African indigenous legume that shows great potential to improve the food and economic security of small scale farmers living in semi-arid regions of South Africa. This study sought to investigate the potential for Bambara groundnut to enhance the food and economic security of small scale farmers in the Capricorn District of Limpopo Province, South Africa. A total of 43 Bambara groundnut producers were interviewed about Bambara groundnut production and their perceived enablers and barriers of utilizing Bambara groundnut. The study found that the majority of Bambara groundnut producers were old (>65 years of age), female small scale farmers who produced the crop for primarily household use. There were however a small number of farmers who produced Bambara groundnut on a larger scale, mostly to sell. Most farmers perceived that local demand was higher than supply and were able to obtain a high market value for Bambara groundnut. There appeared to be potential economic opportunities for many of the farmers to sell Bambara groundnut. The main reason why most farmers in this study did not sell Bambara groundnut was because the yields they obtained were too low. The main enablers perceived by farmers for Bambara groundnut production were a) The high nutritional value of Bambara groundnut; b) The good taste of the seeds; c) The nitrogen fixation properties of this legume and its ability to improve soil fertility; d) The legume intercrops well with maize; e) Bambara groundnuts high drought resistance; f) Cultural traditions associated with Bambara groundnut; and g) Use as animal feed. The main barriers were a) Low yielding characteristics of Bambara groundnut; b) Lack of available farmland; c) Lack of irrigation; d) Poor land management practices; e) Low soil fertility; and f) The crop's susceptibility to water logging. Overall the farmers were positive about Bambara groundnut production and could potentially benefit from advancements made in this sector of agriculture. The study concludes with recommendations to help improve small scale farmers' production of Bambara groundnut with the aim of improving their food and economic security.

Table of Contents

Chapter 1: Introduction

1.1: Introduction to the Study

Achieving world food and nutritional security will be one of the greatest global challenges in the 21st Century. A paradigm shift in food systems is required in order to sustainably feed a growing world population, whilst coping with the predicted outcomes of climate change (FAO 2011). Although major crops will continue to play the primary role in addressing world food security, an increased utilization of a wider range of crop species will be vital to the creation of sustainable, resilient and nutrition-sensitive agricultural systems in the long term (Mayes et al. 2012; McLachlan and Landman 2013). The United Nations Food and Agricultural Organisation (FAO) crowned 2016 as the year of the pulses, with the recognition that pulses provide a healthy and nutritious food source and offer a sustainable solution for feeding the planet (UN 2014). Pulses can enhance the sustainability and resilience of cereal based farming systems and are often an important food source for many rural poor farming communities, providing a cheap source of protein that has a long shelf life (Stagnari et al. 2017). This stresses the need to promote and enhance world legume production.

Bambara groundnut (*Vigna subterranea*) is an African indigenous pulse that is predominantly cultivated in sub-Saharan Africa by small scale female farmers (Bamshaiye et al. 2011). The crop has high drought resistance and can produce reasonable yields under marginal conditions, making it potentially highly beneficial to resource poor farmers by being ''a good backstop for hungry times'' (Mkandawire 2007). Bambara groundnut has been referred to as an indigenous solution to Africa's food crisis, as it provides an almost complete food source (Jieani 2016). In particular, Bambara groundnut is a good source of protein, and is high in the essential amino acid lysine, which is often low in cereals, thus making it an effective food source for complementing a cereal based diet (Baudoin and Mergeai 2001; Omoikhoje 2008).

Bambara groundnut is a nitrogen fixator and can be utilized in maize based farming systems to improve soil fertility (Musa et al. 2016). For small scale farmers in South Africa, maize is the most important staple and cash crop (Moriri et al. 2015; DAFF 2016). Poor soil fertility is often a major constraint to maize yields obtained by small scale farmers: these farmers are often located on marginal land, are resource poor and cannot afford to purchase fertilizer (Mpandeli and Maponya 2014). Bloem et al. (2009) argues that the utilization of legumes is an affordable and sustainable method of enhancing soil fertility and maize productivity for small scale farmers in South Africa, however currently the utilization of such crops by the farmers is low. Intercropping Bambara groundnut with maize has been seen as an effective method of improving the sustainability of maize production, whilst improving the efficiency of land use (Alhassen and Egbe 2013a); land availability is also a major constraint to small scale farmers in South Africa (Mpandeli and Maponya 2014). Crop models indicate that there is large potential for cultivation of Bambara groundnut in the semi-arid regions of South Africa (Azam-Ali et al. 2001). Climate models also indicate that the short-to-mid-term projections of climate change within this region would also favour the crop (Azam-Ali et al. 2001; Karunaratne et al. 2015). Whilst current Bambara groundnut markets in South Africa are predominantly local, the recent developments in premium value-

added foods that can be produced using Bambara groundnut could offer future opportunities for farmers to economically benefit by cultivating this crop (Murevanhem and Jideani 2013).

Bambara groundnut has great potential to enhance the food and economic security of many small scale farmers in semi-arid regions of South Africa. Not only does Bambara groundnut produce a highly nutritious food source, but the crop is highly adapt at surviving in drought prone areas. Furthermore Bambara groundnut can be incorporated into maize based farming systems to enhance the farms sustainability and productivity. Based on a thorough literature review and from an experts opinion on Bambara groundnut production in South Africa (Dr C Madakadze 2016, *pers.comm*, June) there is currently little information about how Bambara groundnut is utilised by small scale farmers in South Africa. Furthermore, it appears as though few studies have been conducted in the country which have assessed farmer's perceptions of Bambara groundnut production. There are however a number of studies conducted in Ghana, Nigeria and Kenya that have assessed farmers' perceptions of Bambara groundnut (Berchie et al. 2010a; Alhassan and Egbe 2013b; Akpalu et al. 2013; Wasula et al. 2014; Adzawla et al. 2016a Adzawla et al. 2016b). The study will investigate small scale farmer's perceptions of Bambara groundnut as well as their production methods and utilization of the crop. This study attempts to reduce the knowledge gap on small scale farming of Bambara groundnut in South Africa and in doing so, gain an insight into the potential for enhancing food and economic security of these farmers. The study may also reveal opportunities to support and enhance their farming strategies for Bambara groundnut, as well as storage methods and marketing strategy. This study was conducted in the Capricorn District of Limpopo Province, which is a semi-arid region and is one of the known major production areas for Bambara groundnut in South Africa (Conradie 2012; DAFF 2016). The researcher acquired qualitative and quantitative data from 43 Bambara groundnut producers in the region in order to understand how farmers utilize Bambara groundnut, as well as to identify what they perceive as the enablers and barriers to the crop's production. I hypothesize that Bambara groundnut production has great potential to be utilized by small scale farmers in semi-arid regions and advancements in Bambara groundnut production methods could improve their food and economic security.

1.2: Aims and Objectives of the Study

This study had two primary aims. The first aim was to determine the current role of Bambara groundnut in farmer's food and economic security strategy. The second aim was to develop an assessment of the potential for Bambara groundnut production to enhance their food and economic security in the future. For this purpose the following objectives were devised:

1. To understand the primary purpose of Bambara groundnut production and how this fits with the wider farming strategies utilized by farmers.
2. To determine the yields of Bambara groundnut obtained by the farmers and understand the main underlying factors determining yields.
3. To understand how farmers store Bambara groundnut, as well as identify the key pests and diseases that affect Bambara groundnut.
4. To ascertain the farmers' perceived enablers and barriers to Bambara groundnut production.

5. To investigate the economic opportunities that may arise from Bambara groundnut production.

It was agreed between the researcher and the Agricultural Extension Officers that the findings of this study would be shared with them so that they can then relay the key findings to farmers who participated in the research. The researcher would like to support the farmers in improving their food and economic security. Therefore if the findings reveal opportunities to support farmers' Bambara groundnut production through relevant agri-business, NGOs or research institutes then the researcher will attempt to establish collaboration between them. For example if storage pests are a major issue for Bambara groundnut production by farmers, then the researcher will contact relevant NGOs, as well as agri-business who may be interested in to see if they can assist in providing pest resistant storage devices.

1.3: Outline of Dissertation

This research is presented in 7 Chapters. Following the introduction is the background literature to the study, which situates the theory and importance of the study. Chapter 3 provides the methodology and region for the study. Chapter 4 presents all results obtained in the study. Chapter 5 is the analysis. Chapter 6 provides a summary of the findings from the study and discusses the future potential of Bambara groundnut for small scale farmers. Chapter 7 offers recommendations to support small scale farmers with Bambara groundnut production and suggests ideas for future research to support Bambara groundnut producers in South Africa.

Chapter 2: Literature Review

2.1: Introduction

Global food security is becoming increasingly reliant on a small number of major food crops, and globally agricultural systems are reducing in agrobiodiversity (Khoury et al. 2013). The major 5 crops (wheat, rice, maize, sugar, soybean) account for approximately 67% of global directly consumed calories (Clay 2010). Major crops will continue to play the primary role in addressing world food security; however, an increased utilisation of a wider range of crop species will be vital to the creation of sustainable, resilient and nutrition-sensitive agricultural systems (Mayes et al. 2012; McLachlan and Landman 2013).

The United Nations Food and Agricultural Organisation (FAO) declared 2016 the year of the pulses, with the intention of creating a unique opportunity to promote and improve the further utilization of pulse crops within food systems (UN 2014). The use of pulses has been identified as a method of improving the sustainability, stability and resilience of farming systems (Dwivedi et al. 2015; Stagnari et al. 2017). Pulses provide a healthy and nutritious food source and often act as a vital source of protein for resource poor farmers (Iriti and Varoni 2017). Drought resistant and water efficient legumes (including Bambara groundnut) have been identified to be vital components in enhancing food and nutritional security in water scarce regions (Chivenge et al. 2015). Legumes can improve the sustainability of cereal based farming systems due to their nitrogen fixation characteristics and ability to improve soil fertility (Bloem et al. 2009; Nyalemegbe and Osakpa 2012; Bonsu and Asibuo 2013; Ibeawuchi 2013; Brooker et

al. 2015). In semi-arid regions, drought resistant legumes appear to show great potential for enhancing farmer's food and economic security. Furthermore, legumes can be utilized by farmers, alongside traditional cash crops in order to improve the long term sustainability of farming systems.

2.2: Food Security in a South African Context

Food security ''exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'' (FAO 2010). Whilst on a national scale South Africa is considered food secure, on a household level there exists a large amount of food insecurity (Altman 2009; Labadarios et al. 2011; Hendriks, 2014). The South African National Health and Nutrition Examination Survey (SANHANES-1), conducted in 2012, showed that out of all nine Provinces in South Africa, Limpopo overall had the second highest prevalence of food insecure households, with 27.3% of people at risk of hunger and 30.8% experiencing hunger (Shisana et al. 2014). In addition, Limpopo households scored the lowest mean dietary diverse score and was the province with the highest percentage of people who had a dietary diversity index lower than 4 (Shisana et al. 2014). Further studies indicate that over half of rural households in Limpopo were considered as severely food insecure and approximately one quarter were considered moderately food insecure (Sakyi 2012; De Kock et al. 2013; Masekoameng and Maliwichi 2014). In South Africa, poverty and food insecurity are strongly interlinked and whilst historically, food in rural areas was predominantly produced by small scale subsistence farmers, the majority of people now living in rural areas buy their food and so monitory income of a household is the main determinant of food security (Sakyi 2012; Cock et al. 2013; Masekoameng and Maliwichi 2014). Food prices in South Africa are increasing and this has a disproportionate impact on the monetary poor who are unable to afford micronutrient rich foods such as fruit and vegetables and increasingly buy calorie dense foods such as those containing high amounts of fats and oils, added sugar and refined grains (Ruel et al. 2004; Faber and Drimie 2016). The absence of enough micronutrients in a diet can lead to physical and mental diseases (Bain et al. 2013). Small scale farming however still continues to be an important element of rural household food security strategy in South Africa, and often provides an important contribution to their micronutrient intake (Averbeke and Khosa 2007; Baiphetthi and Jacobs 2009; Sakyi 2012; Tibesigwa and Visser 2015).

2.3: Introduction to Bambara Groundnut

Bambara groundnut (*Vigna subterranea*) is an African indigenous legume, which is predominantly cultivated by small scale female farmers in Sub-Saharan Africa (De Kock Undated; Heller et al. 1997; Greenhalgh 2000; Mkandawire and Sibuga 2002; Bamshaiye et al. 2011). The crop is also cultivated in small quantities in America, Asia, the Middle East and Australia (NRC 1996; Suwanprasert et al. 2006). Due to the lack of data it is difficult to estimate the total amount of worldwide Bambara groundnut production, however Hillocks et al. (2012) believes that the most frequently used figure in literature for worldwide Bambara groundnut production annually is 330,000 tonnes, and this figure was originally derived by Coudert (1984).

Bambara groundnut bean is predominantly cultivated for human consumption, however its leaves are regularly used by farmers as animal feed (Massawe et al. 2002). Bambara groundnut has been described as a ''complete food'' by some researchers, due to its well-balanced nutritional profile (Ijarotimi and Esho, 2009; Mahala and Mohammed, 2010; Ouédraogo et al. 2012). Bambara groundnut contains approximately 15-25% protein, 50%-65% carbohydrate, 5-7% fat, 3-10% fibre, 3-5% ash and 2% mineral (De Kock Undated; Amarteifio and Moholo 1998; Omoikhoje 2008; Mazahib et al. 2013; Yao et al. 2015). It is a good source of protein and in particular contains a high amount of the essential amino acid lysine, which is generally low in cereals and therefore complements a cereal based diet (Baudoin and Mergeai 2001; Omoikhoje 2008). Bambara groundnut contains a good source of dietary fibre, which helps with digestion and has also been found to reduce the risk of certain diseases such as obesity, diabetes, coronary heart disease, some cancers and haemorrhoids (Hawkes 2006; Wood and Grusak 2007; Daou et al. 2011; Yao et al. 2015). Bambara groundnut is also high in the amino acid methionine and is a good source of calcium, iron and potassium (De Kock Undated). Due to the high nutritional value of Bambara groundnut, the crop has been described as ''a native solution to Africa's food crisis'' (Stone et al. 2011). Once the Bambara groundnut seed is harvested, it can be consumed within a short term period whilst fresh, or dried and stored for later consumption (Hillocks et al. 2012). Fresh Bambara groundnut is often considered as a delicacy, which often causes a shortage in the locality it is produced (Greenhalgh 2000).

Bambara groundnut is a highly adaptive crop and is known to grow in a wide range of agro-ecological conditions, from semi-arid regions to rainforests and in cool, moist highlands (NRC 2006; Onwubiko et al. 2011). In particular, Bambara groundnut has a high drought tolerance and has a high water use efficiency (Mwale et al. 2007; Berchie et al. 2012 Shareef et al. 2013; Mabhaudhi et al. 2013). The crop is able to produce reasonable yields, with minimal inputs, in areas of low rainfall and poor soil fertility, making it a highly accessible crop for resource poor farmers to cultivate in semi-arid regions (De Kock Undated; Alhassan and Egbe 2013b). Due to Bambara groundnuts nitrogen fixation properties, the crop can provide a net N return to soils providing that crop residues are returned to the soils, once the crop has been harvested (Dakora and Keya 1997; Ncube et al. 2007; Kgonyane 2010; Odhiambo 2011; Nyalemegbe and Osakpa 2012). However, the amount of N fixation is not sufficient for cereal crop production and additional supplement of N is needed (Ncube et al. 2007; Nyalemegbe and Osakpa 2012). Bambara groundnut's physical characteristics of being a small, short structured crop combined with the crops nitrogen fixation abilities make it an effective partner for cash crops such as maize, sorghum and cassava (Karikari 2000; Alhassan and Egbe 2013a; Jacob et al. 2014).

Whilst there are many enablers for Bambara groundnut production, particularly in semi-arid regions of sub-Saharan Africa, the crop has received very little research attention, with efforts largely focusing on more established commercial crops (Adzawla et al. 2016b). This has led to a lack of improved varieties of Bambara groundnut, with farmers resorting to growing unimproved, low/ unpredictable yielding, locally derived landraces (Massawe et al. 2005; Alake et al. 2015). As a result, small scale farmers commonly obtain low yields of Bambara groundnut, typically ranging between 250-600kg/ha (Heller et al. 1997; Azam Ali et al. 2004; Fleissner 2006; Berchie 2010a; Hillocks et al. 2012). In controlled field trails, yields between 2,500-3,500kg/ha have been reported (Swanevelder 1998; Collinson et al. 2000; Matthews 2013; Mabhaudhi et al. 2013; Shiyam et al. 2016) showing that the crop has potential to produce high yields. Another barrier to farming Bambara groundnut is the long cooking time required for mature seeds, which is a major disadvantage for resource poor farmers, who often lack both time and resources to cook Bambara groundnut (Berchie 2010a). Whilst Bambara groundnut is considered to be overall

relatively pest free (Hillocks et al. 2012; Mkandawire 2007), several studies have highlighted that it is susceptible to weevil attack during storage (Golob et al., 1998; Cork et al. 2009; Magagula and Maina 2012; Ayamdoo et al. 2013; Akpalu et al. 2013; Nyamador et al. 2016). The crop is often grown by resource poor farmers and as a consequence, is often perceived as a 'poor persons' crop, which discourages some farmers from producing it (De Kock Undated). In many countries, the crop is traditionally considered as a 'women's crop', which Mkandwire (2007) argued reduced its status in the view of farmers; Kuznesof (1997) thought that traditional and indigenous crops in South Africa are often perceived as 'old fashioned' and regarded as 'poor people's food'. However more recent research in South Africa showed that the majority of rural people do not have these biases of indigenous crops and in fact highly appreciate these crops due to their high nutritional value and affordability (Van der Hoeven et al. 2013; Cloete and Idsardi 2013).

2.4: Bambara Groundnut production In South Africa

The most common names for Bambara groundnut in South Africa are "jugo beans" or ''njugo beans'' (Swanevelder 1998). Other common names for Bambara groundnut within the Limpopo region are include ''Ditloo- marapo'' (Sepedi) ''Phonda'' (Venda) and ''Tindhluwa '' (Tsonga) and ''Jugoboon'' (Afrikaans) (Mohammed 2014). For small scale farmers in South Africa, overall Bambara groundnut is considered to be the third most important grain legume crop after groundnut and cowpea (DAFF 2016); however, in certain regions such as the low and middle veld regions of Mpumalanga, small scale farmers consider Bambara groundnut to be the third most important crop after maize and groundnut (Matthews 2013). Bambara groundnut is most commonly intercropped by small scale farmers, with maize, cowpeas and melons, although it is sometimes planted as a sole crop, with plot sizes ranging between 300 to 2500 m^2 per farmer (Swanevelder 1997; Swanevelder 1998; Asiwe 2009; DAFF 2016). Most of Bambara groundnut production in South Africa occurs in Limpopo, Mpumalanga, North West, Gauteng and KawZulu-Natal provinces. The major regions in Limpopo where Bambara groundnut is produced are in the districts of Capricorn, Waterburg, Mopani and Vhembe (DAFF 2016).

There are no reliable production figures for Bambara groundnut in South Africa (Greenhalgh 2000). In South Africa, all Bambara groundnut production is by small scale farmers and the crop is not grown commercially (Swanevelder 1997; DAFF 2016). Very little literature is available that describes small scale farming of Bambara groundnut in South Africa. Matthews (2013) provided an overview of indigenous crops cultivated by small scale farmers in Mpumalanga, which also described Bambara groundnut. Swanevelder (1997; 1998) has also provided an insight into how small scale farmers utilize Bambara groundnut, with Swanevelder (1997) providing detail of the cultural usage of Bambara groundnut. The South African Department of Agriculture, Forestry's and Fisheries have produced a Bambara groundnut production guidelines manual, which provides a general description of Bambara groundnut production in South Africa (DAFF (2013; 2016). Most of the Bambara groundnut produced is for subsistence use, and it is only relatively recently that people in South Africa have been selling Bambara groundnut (DAFF 2016). Greenhalgh (2000) estimates that the size of the South African market ranges between 1,500-4000 tons, with a sizable proportion of the supply being met by imports from Zimbabwe. The largest exporter of Bambara groundnut is Zimbabwe exporting approximately 2,000-3,000 tons a year, most of which is believed to be shipped to South Africa (Greenhalgh 2000). According to Swanevelder (1998), a 1kg bag of Bambara groundnut would cost between 3-20 rand per kilogram. Overall it appears as though

the total Bambara groundnut production in South Africa is small. In 1998 the cost of Bambara groundnut in South Africa was believed to be around 3-20 rand per kilogram (Swanevelder 1998). It's believed that in South Africa the demand for Bambara groundnut exceeds supply (Swanevelder 1998; Greenhalgh 2000). Controlled trails of Bambara groundnut have been conducted in Alma (Limpopo), Potchefstroom (Pretoria), Ukulinga Research Farm (KwaZulu-Natal) and Roodeplaat (Pretoria) (Swanevelder 1998; Sinefu 2011; Mabhaudhi et al. 2013). Sinefu (2011) and Mabhaudhi et al. (2013) found that the date of planting Bambara groundnut, as well as the treatment (irrigated or non-irrigated) significantly affected Bambara groundnut yields. None of the current studies however do not provide details as to Bambara groundnut yields obtained by farmers, the economic opportunities of Bambara groundnut or what farmers perceive the barriers and enablers to Bambara groundnut production to be.

In South Africa, Bambara groundnut is consumed both in its fresh and dried state, although it is believed that it is mostly consumed whilst it is fresh (Greenhalgh 2000). Whilst fresh it is often eaten on its own as a snack or mixed with maize and groundnut (Masindeni 2006). Maisindeni (2006) also reports that in South Africa dried Bambara groundnut are pounded to a flour and boiled to make a stiff porridge, or the seeds are boiled and then mixed with samp or used to make soup. Studies in South Africa have reported folklore, superstitions and cultural beliefs that likely influence Bambara groundnut production in South Africa, however it is currently unclear as to the extent that these beliefs persist in the country. Swanevelder (1997) mentioned several folklores and superstitions related to Bambara groundnut production in South Africa. For example in certain regions, when a village chief died, people were prohibited from growing Bambara groundnut for between 1-5 seasons. Other examples of these cultural practices included restrictions on the planting of Bambara groundnut on male owned land to either every other year and sometimes males were restricted from walking through Bambara groundnut fields as this was believed to result in bad yields. Cultural tradition around the Mpumalanga region frequently prohibited early planting (before January) of Bambara groundnut, which consequently shortened the growing season and led to lower yields (Matthews 2013).

In South Africa there are no cultivars of Bambara groundnut and farmers cultivate Bambara groundnut as a mixture of landraces (Unigwe et al. 2016). Compared to other Bambara groundnut accessions in other countries, it appears that most local Bambara groundnut accessions in South Africa are low yielding (Fleissner 2006). Matthews (2013) reported that South Africa's Department of Agriculture and Land Administration had identified local accessions in Mpumalanga for high yielding Bambara groundnut with yields of up to 2355kg/ha (local accessions MPB51 and MPB71). Shegro et al. (2013) and Unigwe et al. (2016) described morphological variation of a total of 41 accessions of Bambara groundnut that are present in South Africa by measuring 18 phenotypic morphological traits of Bambara groundnut. Unigwe et al. (2016) found suitable yield related traits in Bambara groundnut accessions B7-1, SB4-4C, SB19-1A, Bambara-12 and SB16-5A, and the Bambara groundnut accessions SB11-1A, SB19-1A, SB12-3B and Bambara-12 possessed good vegetative traits. It therefore appears that there is a large potential to develop high yielding Bambara groundnut in South Africa.

The BAMnut model, described by Azam-Ali et al. (2001), has been developed to predict the suitability of different regions of the world to grow Bambara groundnut. The model calculates that 53% of South Africa was considered suitable to generate Bambara groundnut yields of between 1,000-3,000kg/ha. The Aquacrop models appears to predict the yield performance of several South African Bambara groundnut landraces with a high level of accuracy (Mabhaudhi et al. 2014). Karunaratne et al. (2015) modelled Bambara groundnut yields, using CMIP5-RCP9.5 climate models and the Bambara groundnut Aquacrop

model in Botswana, South Africa and Namibia. The results were that whilst South Africa had the lowest yield under current climatic conditions, future predicted warming will likely cause increased yields for Bambara groundnut. It has also been argued that in a water scarce country such as South Africa, it may be prudent to increase the utilization of water efficient African indigenous crops such as Bambara groundnut (Chivenge et al. 2015). In the future therefore there may be further opportunities and incentives for increased Bambara groundnut production in South Africa.

2.5: Small Scale Farmers in Limpopo and South Africa

South Africa has a dualistic agricultural system, which developed during the Apartheid era, comprising of a small number of predominantly white large scale farmers and a large number of small scale black farmers (Vink & Kirsten, 2003; Aliber & Hart, 2009). In the year 2000, there were 273,000 small scale farmers participating in small scale agriculture in Limpopo (Oni et al. 2012). Within the Limpopo region, it is believed that approximately 80% of small scale farmers are female and the average land size is approximately 1.5ha (Oni et al. 2012). Some of the main constraints faced by these farmers include high fertilizer costs, availability of land, a lack of irrigation, lack of credit and insufficient land availability (Van Averbeke et al. 2011; Maliwichi et al. 2012; Van Averbeke and Khosa 2013; Mpandeli and Maponya 2014). Maize is the most important grain crop and for most small scale farmers in South Africa it serves as their most important staple and cash crop (Hlongwane et al. 2014; Moriri et al. 2015). Small Scale farmers often obtain low maize yields due to declining soil fertility, which is more pronounced in the semi- arid regions of Limpopo due to low and erratic rainfall, with soils predominantly sandy, which have poor water holding capacity, are low in organic matter and have low nutrient levels (Moriri et al. 2015). Droughts are another major challenge for small scale farmers living in semi-arid regions of Limpopo. South Africa's drought in 2016, described by AgriSA (2016) as '' the most severe El Nino-induced drought for decades'' highlighted the devastating affect drought has on agriculture and particularly cereal crops such as maize. The mean temperature in South Africa is expected to rise between 2.3°C to 3.9°C by 2050 and 3.9°C to 9.6°C by 2100 (Dube et al. 2013). Extreme weather patterns are likely to increase along with an increase in inter-annual variability of rainfall (Hewitson and Crane, 2006). Water availability is already South Africa's main limiting factor in agriculture and water supplies will become increasingly strained in the future due to the effects of climate change, increased demands from urban areas and energy production (Carter and Gulati 2014). In Limpopo in particular, the long term Outcomes of climate change will likely cause an increase in temperature and decrease in precipitation, which will overall have a net negative impact on agriculture within the province, and in particular on maize yields (Maponya 2012; Akpalu et al. 2015). Because many of the farmers in the region are resource poor, suitable 'adaptation' strategies will need to be cheap and accessible. The utilization of legumes in maize based farming systems could be an effective strategy to enhance soil fertility and increase maize productivity for small scale farmers, however the utilisation of legumes by small scale farmers in South Africa is low (Bloem et al. 2009). This is likely due to fact that it is often more cost effective in the short/medium term, for farmers to sole crop maize rather than to intercrop with legumes (Waddington 2007). In Limpopo a number of farmers do incorporate legumes into their farming systems, with the most common ones being groundnut and cowpea (DAFF 2010; 2011), however there are certain drawbacks with cultivating these legumes. Asiwe (2009) found that in the Limpopo province, cowpea has a high susceptibility to pests , in particular, aphids and viral diseases which can cause complete crop failure. Groundnut

production in South Africa is declining and is highly susceptible to drought, with 2016 being the lowest production levels of groundnut since 1946 (AgriSA 2016). Bambara groundnut is also sometimes used by small scale farmers in Limpopo, but only to a very limited extent (DAFF 2016). It has been argued that a primary reason why Bambara groundnut is given low priority by farmers relative to other legumes such as groundnut and cowpea is because more research has been done on these crops and improved varieties have been developed in contrast to Bambara groundnut which has had little attention and hence no improved varieties. (Massawe et al. 2005; Mkandawire 2007). Bambara groundnut is often considered to have a high resistance to pests in the field and has a high drought resistance (Mkandawire 2007; Hillocks et al. 2012; Shareef et al. 2013). Due to the pest constraints of cowpea and low drought resistance of groundnut, the further utilization of Bambara groundnut could improve the resilience of small scale farmers' production strategies.

2.6: Conclusion

There is a large number of people living in Limpopo, who rely on small scale agriculture as part of their food and economic security strategy. Many of these small scale farmers are resource poor and struggling to maintain food security. Therefore it is important that small scale farmers are supported by the research community to enhance their farming productivity and resilience under projected future climatic impacts. Because farmers have limited resources, methods to support the farmers need to be cheap and accessible. Legumes can provide a healthy nutritious food source and can be utilized to improve soil fertility and reduce fertilizer costs. An increased utilization of legumes by small scale farmers could therefore be a cheap and accessible method to enhance maize based farming systems. Bambara groundnut could be particularly useful for farmers living in semi-arid regions because of its high drought resistance. There has been little research conducted in South Africa on how small scale farmers utilize Bambara groundnut. In several other African countries however, the crop appears to be an important element in small scale farmers food security strategy, acting as a ''good backstop for Hungry times'' (Mkandawire 2007). Bambara groundnut could therefore play an important role in small scale farmer's food security. Whilst the literature states that Bambara groundnut is sold in South Africa, the extent to which farmers in South Africa market Bambara groundnut is currently unclear. It is also unclear as to how many of the cultural beliefs described by Swanevelder (1998) influence the crops production. There also have been no studies on farmer's perceptions of enablers and/or barriers to Bambara groundnut production in South Africa, however similar studies have been conducted in Nigeria and Ghana. It is important to recognize farmer's views of Bambara groundnut, in order to understand the extent to which Bambara groundnut can support farmer's food and economic security. This research therefore will attempt to further the research communities understanding of small scale farmer's utilization of Bambara groundnut as well as document what the farmers perceive as the main barriers and enablers to Bambara groundnut production.

Chapter 3: Methodology and Region of Study

3.1: Introduction

Chapter 3 outlines the methodology used to assess the farmer's utilization of Bambara groundnut and their perceptions of the enablers and barriers to Bambara groundnut production. The chapter begins with a description of the study sites followed by the process of initial selection of the farming communities interviewed in this study. The next section then discusses the research approach, research design and data collection methods used. The final section concludes with data analysis techniques as well as the studies limitations and biases.

3.2: Initial selection of region for study

The sites chosen for this research were all located in the Capricorn district, which is situated within the Limpopo province of South Africa. Figure 1 is a map of South African provinces and Figure 2 shows the Capricorn District, in relation to the other districts within the Limpopo province. Capricorn district is one of the main areas known for Bambara groundnut production in South Africa (DAFF 2016). The main reason why the researcher chose to conduct this study in the Capricorn District is because the region experiences a semi-arid climate and therefore is likely one of the regions where Bambara groundnut may be useful to small scale farmers. The researcher also choose this region, because it is situated near the city of Polokwane, which is where the provincial office of the Department of Agriculture, Forestry and Fisheries is located and is also close to the University of Limpopo. It was through contact with Professor IK Mariga at the University of Limpopo that the researcher was made aware of the Department of Agriculture, Forestry and Fisheries satellite office at Mankweng. Agricultural extension officers from both the provincial office of the Department of Agriculture, Forestry and Fisheries and the satellite office in Mankweng helped locate suitable sites for this research.

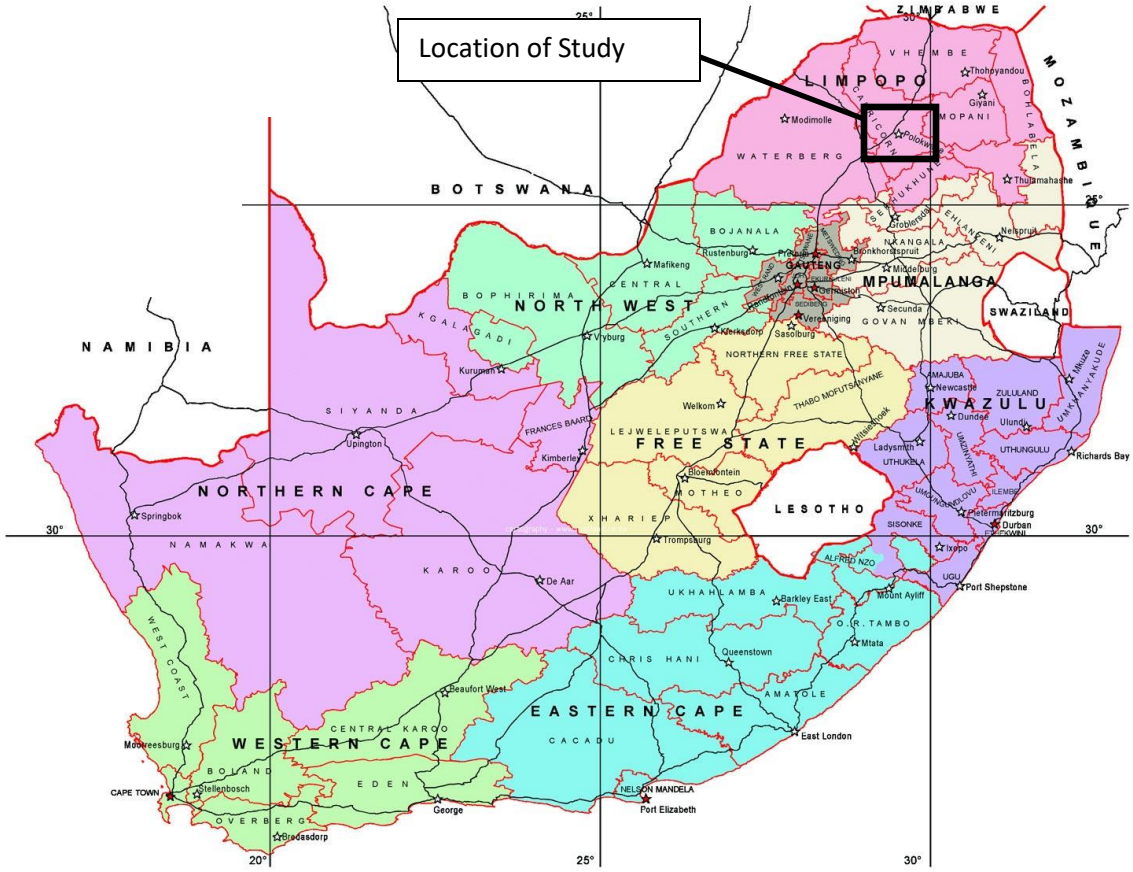

Figure 1: Map of South Africa showing the region where field research took place

3.3: Description of Sites

The five villages selected for the study were Perskebult (23.805649°S, 29.349643°E), Ga Ramphere (24°1'0" S and 29°46'0" E), Makatiane (24.090908°S, 29.713975°E), Ga Mogano (24.046818°S, 29.742603°E) and Ga Molepo (24.048462°S, 29.779071°E). All villages were situated within a 40km radius of the city of Polokwane, capital of Limpopo Province, South Africa (See figure 2). The villages Ga Ramphere, Makatiane, Ga Mogano and Ga Molepo were identified as suitable sites for the study by the agricultural extension officers from the Department of Agriculture, Forestry and Fisheries satellite office at Mankweng. The researcher felt that the research required a larger sample size of farmers and the agricultural extension officers from this office were not aware of any more suitable villages to interview additional farmers. In order to acquire an additional site, the researcher contacted agricultural extension officers at the provincial office of the Department of Agriculture, Forestry and Fisheries, in the city of Polokwane, who suggested Perskebult as a suitable village to interview additional farmers. The altitude of the villages ranged between 1120m to 1250m and according to the Köppen-Geiger climate classification system described by Kotteck et al. (2006), the region experiences a cold semi-arid climate (Conradie 2012). Mean annual rainfall in the region is 478mm (compared to a global average of 860mm), with the majority of rainfall occurring during the summer (Ojo and Owolawi 2014). Mean diurnal temperatures in the study area are between 22 °C during summer time and 12°C during winter. During

the summer, average temperatures range between 20-22°C, reaching up to 38°C during the daytime. In winter, the average temperature can fall to 11°C and minimum temperatures can be below -3°C. Mean pan evaporation rates are high and exceed 2000 mm yr^{-1} (Finch et al. 2003). Droughts are a common phenomenon in the region and interviews occurred during a severe drought period. On the ground this resulted in complete failure of all major crops, including maize for farmers without irrigation. Farmers with access to irrigation also experienced crop losses, however the losses were not as substantial. More details on crop yields will be discussed in the results section. Soils at all study sites were predominantly sandy. The farmers who attended the meetings from the villages Perskebult and Ga Molepo had irrigation from local boreholes, with the former using furrow irrigation and the later using drip irrigation. The farmers at Ga Ramphere, Makatiane and Ga Mogano relied on rain to irrigate crops.

3.4: Selection and Initial Communication with Farming Communities

The researcher first established contact with Agricultural Extension Officers from the Department of Agriculture, Forestry and Fisheries provincial office in Polokwane and its satellite office in Mankweng, to discuss the project and seek their support in locating and interviewing Bambara groundnut farmers. Five villages were selected for an adapted Rapid Rural Appraisal (RRA) based on advice given by the Agricultural Extension Officers, who had knowledge of the farming activities in the region and also had a good relationship with the farmers. The Agricultural Extension Officers organised preliminary visits to the five villages to enable the researcher to establish contact with the village chiefs and elders so that he could explain what the project was about and request permission to conduct the RRA in their villages. Once permission had been obtained, group meeting dates with the Bambara groundnut farmers in each village were arranged. The field work was undertaken in June 2016 and a total of 43 farmers (nine farmers from Perskebult, nine farmers from Ga Ramphere, 15 farmers from Makatiane, 5 farmers from Ga Mogano and 5 farmers from Ga Molepo) participated in the meetings held across all villages.

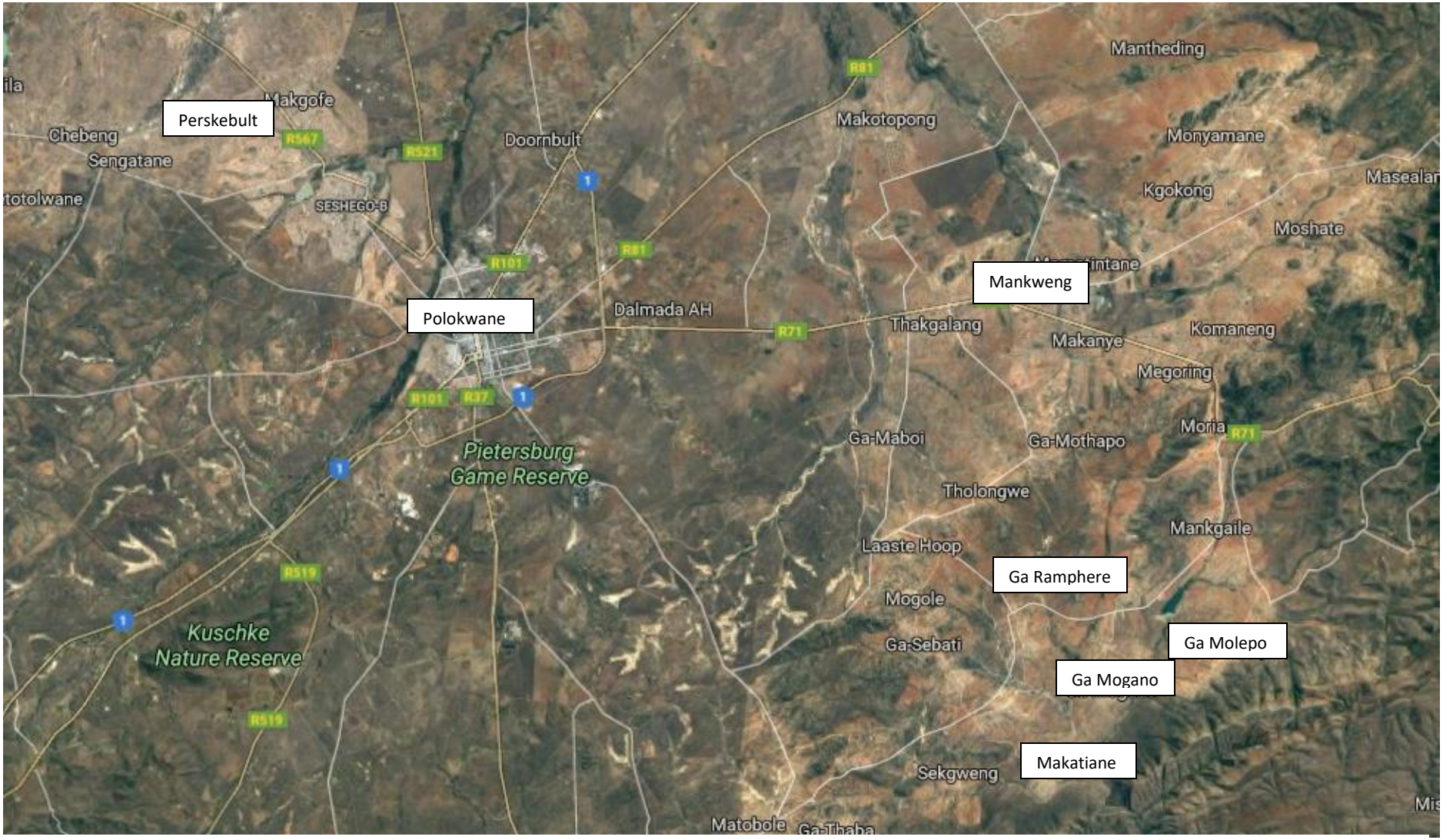

Figure 2: Locations of the five villages involved in this study

3.5: Research Approach

The methodological approach used for this study was an adapted Rapid Rural Appraisal (RRA). There is no strict definition of an RRA due to the flexibility of the research approach (Townsley 1996). The basic concept of a RRA is to quickly gather information on rural conditions and local knowledge on the subject of focus, in close cooperation with the local population, via systematic, semi-structured activities (Cavestro 2003). Examples of semi-structured activities that can be used in an RRA can include in-depth interviews, focus groups and observation studies (Crawford 1997). The basic guidelines to a RRA given by Townsley (1996) are as follows:

- The activity must be structured enough in order to obtain knowledge about the target subject of interest, however flexible enough to accommodate response to the local conditions and circumstances.
- The research must be integrated and multidisciplinary. This requires the use of a multidisciplinary team and a balance of different institutional outlooks
- Participants involved in the RRA may provide biased information. An RRA should therefore seek to reduce biases, be aware of potential biases and be systematic in considering different viewpoints and interests of participants in the study.
- An RRA attempts to accelerate the time taken for the researcher to sufficiently understand the key concepts about the problem of interest.
- RRAs uses a combination of different tools to triangulate the information obtained in order to increase accuracy and comprehensiveness of the study.

In order to collect the information required from small scale farmers for this research, the researcher conducted individual semi structured interviews with farmers, as well as discussion groups with farmers from each village. A questionnaire (See Appendix 2) was devised by the researcher in order to guide both the semi structured interviews and discussion groups. The researcher diverted from the questionnaire when deemed appropriate to accommodate for the farmers answers. In this study the research team in the field consisted of the researcher and the Agricultural Extension Officers. The Analysis of the results also included expert opinion from the project supervisors (Dr Laura Pereira and Dr Peter Johnston) as well as from Dr Casper Madakadze. When possible, the Agricultural Extension Officers as well the people who provided expert opinion were used to triangulate the information obtained from the farmers in order to validate the results. The next chapter will discuss how the interviews and discussions with the farmers was constructed.

3.6: Overview of Interviews with Farming Communities

In total, 43 farmers were interviewed and participated in the discussion groups held at the 5 villages. The number of farmers present at the meetings was dependent on the village elders and village chiefs encouraging the local farmers to participate in these Bambara groundnut discussions. All participants in the interviews and discussion groups were producers of Bambara groundnut and partook in the discussions voluntarily and could leave at any time. Sections 1 and 2 of the interviews (See Appendix B) was completed by interviewing the farmers individually, whereas section 3 was completed through group discussions with the farmers. The number of participants within each discussion group varied

from 5-15. Discussions with the farmers were conducted in Sepedi, with the help of Agricultural Extension Officers who acted as translators for the researcher. Prior to conducting the discussions, the researcher introduced himself and provided background to the study and reasons for undertaking the research. Following this, the researcher presented an ethics approval form, which had been provided to him from the University of Cape Town (See Appendix A). All participants were required to acknowledge and sign up prior to any discussions occurring. The discussions were recorded via a tape recorder as well as on forms that had been constructed prior to the interviews. Each meeting was structured into four main parts, which roughly followed the interview outline shown in Appendix B. Sections 1 and 2 were used to complete Objectives 1, 2, 3 and 5 whilst Section 3 of the discussion was used to complete Objective 4. These sections are discussed in detail below.

3.6.1: Farmers Demographics, Overview of Farming Systems and Purpose of Farming

This section aimed to collect information/data on the demographics of Bambara groundnut producers (age and sex of Bambara groundnut producers), as well as obtain information about their farming systems (size of farms, crops planted, area of land allocated to the crops, yields obtained from each crop during a normal climatic year and also this year (i.e. during a drought period) and what their primary purpose of farming was (i.e. mostly for subsistence use or mostly to sell). This information provided a basic understanding of the farmers' broader strategies and put their use of Bambara groundnut into context.

3.6.2: Bambara Groundnut Production and Utilization of Bambara Groundnut

This section of the interview was designed to understand the scale of Bambara groundnut production by farmers and their farming methods. Farmers were asked questions related to the area of land they allocated to Bambara groundnut production; the kilograms of Bambara groundnut obtained each year; agronomic practices for Bambara groundnut production (planting methods, use of inputs, planting and harvesting dates of Bambara groundnut); main purpose of Bambara groundnut production (i.e. for subsistence use or to sell); storage methods of Bambara groundnut; consumption patterns and consumption methods of Bambara groundnut and marketing of Bambara groundnut (i.e. where farmers sold Bambara groundnut, supply and demand of Bambara groundnut and price obtained for Bambara groundnut). For areas of land where Bambara groundnut was intercropped with maize, only the area of land allocated to Bambara groundnut was taken into consideration (e.g. If 1ha of maize/Bambara groundnut intercropped land consisted of ten 50m x 1m strips of Bambara groundnut and the remainder of land was used for maize, then the farmer would be growing 0.05ha of Bambara groundnut). This was so that the yields per hectare of Bambara groundnut could be compared between all the farmers interviewed. The yields of Bambara groundnut obtained by each farmer per hectare was calculated by multiplying the area of land cultivated by the kilogram of Bambara groundnut the farmer acquired each year.

3.6.3: Farmers Perceptions of the Enablers and Barriers of Bambara Groundnut Production

The aim of Section 3 of the interview was to record what farmers perceived were the barriers and enablers of Bambara groundnut production and their relative importance. The first questions in this section broadly asked the farmers to discuss as a group their reasons were (enablers) and problems (barriers) encountered while growing Bambara groundnut. The researcher asked the farmers to elaborate on each enabler and barrier stated. When possible the researcher refrained from stimulating the discussion by asking about specific attributes of the crop that could have been perceived as a potential enabler and/or barrier to Bambara groundnut production. This was in order to reduce the researchers influence on how the farmers responded. Sometimes however the researcher deemed it necessary to ask about certain attributes of the crop in order to stimulate the discussions. The researcher then asked each farmer to select what they perceived as the main barrier and enabler out of the list generated and provide a reason why. The farmers were then asked to provide a ranking of pre-conceived enablers and barriers. The pre-conceived enablers and barriers used in the ranking assessments were mostly derived from the literature review related to Bambara groundnut, in particular studies which had analysed farmer's perceptions on Bambara groundnut production. Some of the barriers and enablers that formed the pre-conceived list came from the preliminary visits and early discussions with the farmers. The ranking concept was adopted from the methodology used by Alhassan and Egbe (2013), who assessed farmer's constraints to Bambara groundnut production in Nigeria. In the Alhassan and Egbe (2013) study, the ranking scale was only used to assess constraints to groundnut production. In this study the ranking system was used to assess both constraints (barriers) and enablers of Bambara groundnut production. The ranking system used a scale of one-five, with one indicating an enabler/barrier of negligible importance, whilst five indicating an enabler/barrier of most importance. Farmers were allowed to rate multiple enablers and barriers with the same score if they felt that they had a similar impact on Bambara groundnut production (e.g. If both low soil fertility and lack of credit were both considered to be small barriers to Bambara groundnut production, then the farmers would score them both as two). Below provides a breakdown of the scoring system:

1 = The factor was not considered an enabler/barrier to Bambara groundnut production

2 = A small impact to Bambara groundnut production was caused by the factor (a minor enabler/barrier)

3 = Bambara groundnut production was impacted moderately by the factor (an important enabler/barrier)

4 = The factor had a large impact on Bambara groundnut yields (A very important enabler/barrier)

5 = A factor that had a very large effect on Bambara groundnut production (an enabler/barrier of most importance)

3.6.4: Comparative Assessment of Legumes Groundnut, Cowpea and Bambara Groundnut

From both preliminary visits to the villages and early discussions with the village chiefs and elders, the researcher found that it was common for the farmers who produced Bambara groundnut to also produce groundnut and cowpea. From this early observation, the researcher constructed a ranked performance of 11 attributes of the crops that the farmers ranked individually on an interview sheet provided to them. Farmers ranked the legumes from 1-3, with 1 being the best performing and 3 being the worst performing for each attribute. The objective of this was to further understand the reasoning of the farmer's prioritization of the different legumes. The objective of this was to develop a basic understanding of the advantageous and disadvantageous of planting each of the legumes.

3.7: Additional Informal Interviews with Farmers

After the formal discussions described above 15 of the farmers (three from Perskebult, two from Ga Ramphere, five from Makatiane, two from Ga Mogano and three from Ga Molepo) provided the researcher with additional information on Bambara groundnut production. During these detailed discussions, the farmers showed the researcher their farming plots, storage methods of Bambara groundnut, Bambara groundnut landraces that they intended to plant during the next planting season and provided a brief explanation of advantages and disadvantages of each Bambara groundnut landrace.

3.8: Limitations of the Study

Whilst the researcher believes that he tried his best to obtain the best quality data possible, the researcher acknowledges that there were a number of limitations in the methods used for this project. Arguably one of the biggest limitations in this study was that the researcher was only able to interview a small sample of farmers. The ratio of agricultural extension officers to farmers in South Africa is 1:487, and whilst this is better than most African countries, South Africa still has a shortage of agricultural extension officers to support small scale farmers (Akpalu 2013; Davis and Terblanché 2016). Akpaula (2013) found that in certain regions of Limpopo province, 62% of farmers had no contact with agricultural extension officers. One of the agricultural extension officers present stated that the small scale farmers interviewed for this research project had more contact with agricultural extension officers than most other farmers in Limpopo Province would receive (Mrs P Makwela, *pers.comm*. June 2016). It is likely that the good support the farmers obtained from Agricultural Extension Officers in this study had a significant effect on the farmer's perceptions of Bambara groundnut. Another limitation to the study is that some of the answers provided by farmers and the Agricultural Extension Officers, may have been biased as highlighted by Townsley's (1996) study on potential limitations for RRA research. Because the researcher was not able to speak either the main local language (Sepedi) or any other local languages that all the farmers were familiar with, the researcher relied on Agricultural Extension Officers to act as translators and facilitate communication between the researcher and the farmers. The researcher believes that if he had been able to speak the local language, the researcher would have been able to interact better with the farmers and collect higher quality results. In addition, having to work through the village chiefs may have created power dynamics within the discussion groups and may

have influenced the farmer's answers. The field research occurred after a severe drought period. At farm sites that had no irrigation, the drought had caused all crops to fail with the exception of a very small amount of Bambara groundnut. Therefore the researcher was not able to visually assess the normal functioning of the farm sites. The drought may have also influenced the farmer's responses; in particular, their responses to the barriers and enablers to Bambara groundnut production (e.g. for farmers without irrigation, the drought may have caused them to perceive irrigation as a much more important factor than what they would regard it during a normal climatic year). Based on all these limitations stated above, the researcher concludes that the findings from this study may not totally reflect the wider utilization of Bambara groundnut production in South Africa as well as the perceived barriers and enablers to Bambara groundnut production. Therefore the findings from this study should be used with caution when assessing the generally perceived enablers and barriers to Bambara groundnut production across South Africa.

Chapter 4: Results

4.1: Farmers Demographics

Of the 43 farmers interviewed, 79% (34) were female and 21% (9) were male (See Table 1). At Perskebult, Ga Ramphere, Makatiane and Ga Mogano there were considerably more females present at the interviews. At Ga Molepo however there were more males present at the interview. Interestingly, it was found during discussions with the farmers at Ga Molepo that their grandparents were originally from Namibia. From Table 1 it can be seen that the majority of Bambara groundnut farmers interviewed were above the age of 64 (72%), 16% were aged 46-64, 5% were 36-45 and 7% were younger than 35 years old. Four of the five focus groups had most farmers over the age of 64. The exception was Ga Molepo where most farmers were less than 35 years old and male.

Table 1: Gender and Age of Bambara Groundnut Farmers Across All Villages

		Gender		Age (years)			
	Village	Male	Female	<35	35-45	46-55	56+
Numbers	Perskebult	2	7	0	2	2	5
Percentage		5%	16%	0%	5%	5%	12%
Numbers	Ga Ramphere	2	7	0	2	2	5
Percentage		22%	78%	0%	22%	22%	56%
Numbers	Makatiane	2	13	0	0	2	13
Percentage		13%	87%	0%	0%	13%	87%
Numbers	Ga Mogano	0	5	0	0	1	4
Percentage		0%	100%	0%	0%	20%	80%
Numbers	Ga Molepo	3	2	3	0	0	2
Percentage		60%	40%	60%	0%	0%	40%
	Total	9	34	3	2	7	31
	Percentage	21%	79%	7%	5%	16%	72%

4.2: Size of Farm Plots, Main Crops Grown and Purpose of Farming

All farmers interviewed has farm plot sizes ranging between 0.5-3ha and were all located on predominantly sandy soil (see Table 2). The farmers cultivated mixed cropping systems with maize being the dominant crop and their main cash crop as well as their staple food source. The farmers at Perskebult, Ga Ramphere, Makatiane and Ga Mogano practiced a maize-legume intercropping strategy, planting the grain legumes between maize rows. For these farmers, maize was by far the most important crop. The main legumes grown were groundnut, cowpea and Bambara groundnut, with land being allocated in that order. The farmers at Ga Molepo planted maize, Bambara groundnut, groundnut and cowpea as sole stands as part of a crop rotation strategy, with land allocation being prioritized in that order. Other fruits and vegetables such as carrots, onion, cabbage, watermelon, spinach and tomatoes were also grown, however these were all produced on a very small scale and were not investigated in this study. The farmers at Perskebult had access to furrow irrigation, with water access from the Bloed River. The farmers at Ga Molepo had access to drip irrigation, and water was drawn from a local borehole. The farmers at Ga Ramphere, Makatiane and Ga Mogano had no access to irrigation and were therefore solely reliant on the summer rains to irrigate their crops. All ploughing was performed by hired tractor (which cost R850/ha) during summer 2016.

The Agricultural Extension Officers, who were interviewed, believed that during the farmers' early years of farming, all of them practiced mixed farming systems, with maize being their primary crop, followed by legumes such as Bambara groundnut, as well as a number of other crops. This was thought to be the traditional farming strategy that was taught to the farmers by their ancestors. When the Agricultural Extension Officers initially began supporting the farmers, many of them were planting only maize. The Agricultural Extension Officers believed that the farmers had diverted from their family's traditional farming strategy to increasing focus on cultivating maize for several reasons. The reasons stated were: a) improved varieties of maize were available to the farmers; b) Farmers were aware of improved agronomic practices for maize production; c) There were better economic opportunities that derived from cultivating maize monocultures as opposed to cultivating mixed cropping systems. Almost all the farmers had problems with low soil fertility and soil degradation. This was the primary reason why the Agricultural Extension Officers had advised the farmers to revert back to planting legumes as a cover/rotation crop, in order to improve the sustainability of maize production. The extension officers educated the farmers about the nutritional benefits of consuming legumes as well as the benefits that legumes can provide to soils such as improving soil fertility and reduce soil degradation. The extension officers felt that they played a large role in reverting the farmers to cultivating legumes such as Bambara groundnut. It was also stated by the extension officers that the farmers' traditional cultivation methods of legumes such as Bambara groundnut, were not in accordance with the best known agronomic practices. Therefore with regards to legumes such as Bambara groundnut, the Agricultural Extension Officers had advised the farmers on soil preparation, planting depth and spacing, fertiliser application, weed control methods as well as packing method and processing of Bambara groundnut (e.g. making knorx soup out of Bambara groundnut). The extension officers stated that because Bambara groundnut is a minor crop for most farmers, in reality, only a very limited amount of support is given to farmers for Bambara groundnut production.

Maize Productivity and Utilization of Maize

The farmers without irrigation (i.e. the farmers at Ga Ramphere, Makatiane and Ga Mogano) were often obtaining maize yields of <2 ton/ha; the farmers at Perskebult, who had furrow irrigation normally obtained maize yields between 2-5 ton/ha and all the farmers from Ga Molepo who had access to drip irrigation were obtaining yields >10 ton/ha (See Table 2). Due to the low maize productivity achieved by the farmers at Perskebult, Ga Ramphere, Makatiane and Ga Mogano, most of their maize was used for subsistence. Due to the significantly higher maize yields obtained by the farmers at Ga Molepo, whilst some of their maize produced was utilized for subsistence use, the majority was sold. All farmers traded most of their maize to local maize millers in exchange for grain credit and to avoid grain losses during storage. The farmers could either exchange their grain credit for maize meal or sell their grain credit at the South African Futures Exchange (SAFEX) day price. The SAFEX day price is set by the Agricultural Products Division of the Johannesburg stock exchange (Biénabe and Vermeulen 2011), which the milling companies used if the farmers sold their grain credit. For most of the farmers' subsistence needs of maize, grain credit was traded in exchange for maize meal. It was found that farmers could often obtain approximately 50% more for their maize produce if they sold it through local markets (i.e. from their house or at local village/town markets) rather than selling their maize at the SAFEX day price. It was beyond the scope of this study to clarify and comprehensively assess this finding, however a similar finding was reported by (Biénabe and Vermeulen 2011) who assessed small scale farmer's participation in formal grain markets in Limpopo. Due to the higher market price obtained by farmers when selling maize through local markets, farmers tried to avoid selling maize to local millers. It was believed by the Agricultural Extension Officers that generally farmers could sell all their surplus maize (to the local market) if their yield was <2 ton/ha; however, for farmers who attained >2ton/ha, the farmers were not able to sell all of their maize through local markets due to insufficient demand. So that the remaining maize was sold to local maize millers at the SAFEX day price. For this reason, whilst the farmers at Perskebult, Ga Ramphere, Makatiane and Ga Mogano were often able to sell most of their maize through local markets, the farmers at Ga Molepo often had to sell a large proportion of their maize to local millers, as they would have produced on average more than 20 tonne from the 2ha irrigated plot.

Farmers Utilization of Legumes

The farmers from Perskebult, Ga Ramphere, Makatiane and Ga Mogano produced the legumes groundnut, cowpea and Bambara groundnut for mostly household usage; however excess produce was sold locally. The farmers at Ga Molepo produced groundnut and cowpea primarily for household use and Bambara groundnut to sell. Details of the utilization of Bambara groundnut by farmers will be discussed further in the results (see Chapters 4.7 and 4.8).

Table 2: Overview of Farming Systems Utilized By The Farmers In the Five Villages

	Village				
	Perskebult	Ga Ramphere	Makatiane	Ga Mogano	Ga Molepo
Irrigation	Furrow Irrigation	Rain Fed	Rain Fed	Rain Fed	Drip Irrigation
Number of farmers	9	9	15	5	5
Range of plot size (ha)	0.5-3.0	0.5-2.0	1.5	1.0-2.0	2.0
Median plot size (ha)	0.5	1.0	1.5	1.0	2.0
Dominant crop	Maize	Maize	Maize	Maize	Maize
Normal maize yields obtained	2-5 ton/ha	1.5-2 ton/ha	1.5-2 ton/ha	1.5-2 ton/ha	>10ton/ha
Main legumes grown (in order of area grown)	Groundnut Cowpea Bambara Groundnut	Groundnut Cowpea Bambara Groundnut	Groundnut Cowpea Bambara Groundnut	Groundnut Cowpea Bambara Groundnut	Bambara Groundnut Groundnut Cowpea
Ploughing Method	Hired Tractor	Hired Tractor	Hired Tractor	Hired Tractor	Hired Tractor
Method of Planting Bambara groundnut	Plant between maize rows	Plant between maize rows	Plant between maize rows	Plant between maize rows	Sole Crop
Primary purpose of farming	Subsistence/ cash crop	Subsistence/cash crop	Subsistence/cash crop	Subsistence/cash crop	More cash crop orientated

4.3: Farmers Experience with Bambara Groundnut Production and Farming Practices Utilised

All farmers interviewed in this study said that they have planted Bambara groundnut for over 20 years. Soon after all the interviews with the farmers had taken place, the researcher was informed by the Agricultural Extension Officers that many of the farmers at one stage stopped planting Bambara groundnut and were only planting maize. Many of the farmers interviewed were over 65, and were old enough to have accumulated over 20 years experience planting Bambara groundnut, even with an extended period of only planting maize. Bambara groundnut was seen by the farmers as a traditional crop that was introduced to them at an early age by their predecessors. All farmers in this study appeared to have implemented the advice provided by Agricultural Extension Officers; however due to the field research being conducted recently after a drought period, the researcher was not able to visually assess the farmers' cultivation practices.

Planting and Harvesting Dates for Bambara Groundnut

All farmers interviewed planted Bambara groundnut between late October and early December, just after the first rains occur each year. It was also found that only the farmers at Ga Molepo pre-soaked Bambara groundnut seeds for 24 hours before planting, whereas the others did not. The harvesting period of Bambara groundnut is between March and June. To prolong the period that Bambara groundnut can be eaten fresh, farmers would stagger the harvesting of Bambara groundnut and only harvest the crop when it was needed for either household use or as a cash crop. June (when the study was done) was the latest period farmers could harvest the crop.

Recommended Ploughing Depth, Planting Depth and Plant Spacing for Bambara Groundnut

For all farmers ploughing was performed by hired tractor labour. The extension officers said that they advised farmers on the ploughing depth (30-45cm deep), planting space (10-15cm in rows and 45cm-90cm between the rows) and planting depth (2.5-3.0cm) for Bambara groundnut. It was likely that the hired tractor ploughed only at a standard depth of 20-30cm due to the extra time/fuel required for them to plough deeper. The farmers at Ga Ramphere mentioned that they had requested the hired tractor operator to plough the soil deeper, however the hired tractor operator refused. This was seen as a barrier to Bambara groundnut yields obtained (See Table 15).

Fertilizer, Herbicide and Pesticide Used by Farmers

Most farmers interviewed (55%) used both cow manure and NPK fertilizer, 24% of farmers used cow manure only and 21% of farmers did not add any form of fertilizer (See Figure 1). The farmers who used kraal manure obtained it from their own livestock. All farmers who used NPK fertilizer obtained it free as part of the government-sponsored Letsema programme, after soil tests showed very low soil fertility and NPK fertilizer was provided, to be used in addition to kraal manure, in order to improve farmers yields (Mrs P Makwela, *pers.comm*. June 2016). The farmers who used no fertilizer were all from

Perskebult. They were not provided with free NPK fertilizer because although soil tests found that soil quality was low, it was not low enough to qualify for free NPK fertilizer from the Letsema programme. The farmers at Perskebult also did not have livestock, making it harder for them to obtain cow manure. None of the farmers used herbicide or pesticide on Bambara groundnut because it was not considered necessary.

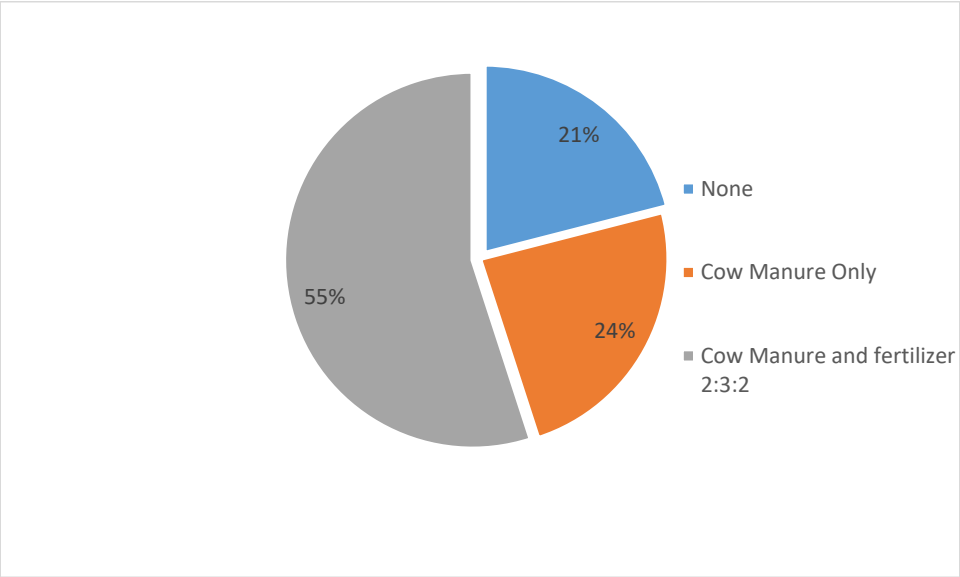

Figure 1: Fertilizer used by Farmers for Bambara Groundnut Production

Planting Method for Bambara Groundnut

The most common method of planting Bambara groundnut was by intercropping it with maize (88% of farmers interviewed) whilst the remaining (12% of farmers) planted Bambara groundnut as a sole crop (See Figure 2). The farmers who intercropped Bambara groundnut with maize were from the villages Perskebult, Ga Ramphere, Makatiane and Ga Molepo, whereas the farmers who sole cropped Bambara groundnut were all from Ga Molepo. Because of the drought, farmers had harvested all Bambara groundnut earlier than in a climatically normal year and the researcher was unable to validate whether the farmers were planting Bambara groundnut in accordance with the planting methods recommended by the Agricultural Extension Officers. It was found that all the farmers planted the 7-8 Bambara groundnut landraces identified (See Figure 4) as a random mixture. There was no assortment of Bambara groundnut seeds for either consumption, for selling or for planting. Mostly the Bambara groundnut seeds planted were obtained from the previous harvest, however if the farmers ran out of seeds, they would buy the seeds from another local farmer.

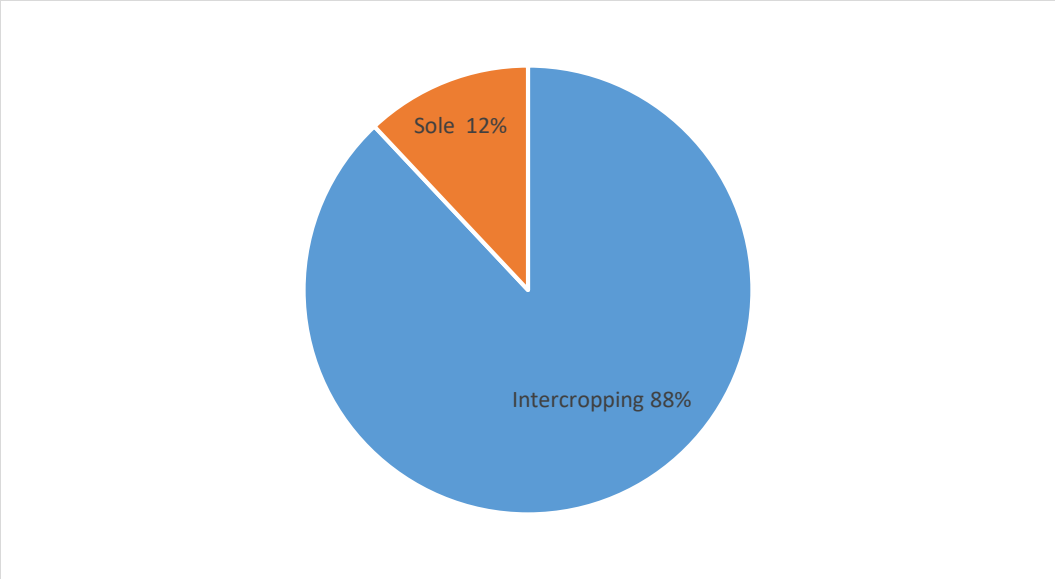

Figure 2: Percentage of Farmers Interviewed who Intercropped Bambara Groundnut with Maize and Sole Cropped Bambara Groundnut

Plot Size Allocated to Bambara Groundnut Production by Farmers

The amount of land allocated to Bambara groundnut and the percentage of total land allocated to Bambara groundnut by each farmer is shown in Table 3. The farmers from Perskebult, Ga Ramphere, Makatiane and Ga Mogano, who intercropped Bambara groundnut with maize, allocated a total area of between 0.04ha-0.13ha to Bambara groundnut production, which equated to 3-9% of their land. In terms of area allocated, these farmers allocated the fourth largest area of their land to Bambara groundnut, with maize occupying the most land followed by groundnut and cowpea. The farmers at Ga Molepo allocated a considerably larger area of their land to Bambara groundnut compared to other farmers interviewed (i.e. 0.5ha), which equated to 25% of their plots of land. Bambara groundnut was thus their second most important crop following maize.

Table 3: Farmers Total Plot Sizes, Area Planted for Bambara Groundnut and Percentage of Total Land Allocated to Bambara Groundnut Production

	Village														
	Perskebult			Ga Ramphere			Makatiane			Ga Mogano			Ga Molepo		
Farmer Number	Total Plot Size (ha)	Bambara Groundnut (m^2)	(%)	Total Plot Size (ha)	Bambara Groundnut (m^2)	(%)	Total Plot Size (ha)	Bambara Groundnut (m^2)	(%)	Total Plot Size (ha)	Bambara Groundnut (m^2)	(%)	Total Plot Size (ha)	Bambara Groundnut (m^2)	(%)
1	3	1250	4.2	2	600	3	1.5	1000	6.7	2	1250	6.3	2	5000	25
2	0.5	450	9	1	600	6	1.5	1000	6.7	1	800	8	2	5000	25
3	0.5	400	8	1	600	6	1.5	1000	6.7	1	700	7	2	5000	25
4	1	600	6	1	600	6	1.5	1000	6.7	2	1000	5	2	5000	25
5	0.5	450	9	0.5	600	12	1.5	1000	6.7	1	600	6	2	5000	25
6	0.5	400	8	1	600	6	1.5	1000	6.7						
7	0.5	300	6	1	600	6	1.5	1000	6.7						
8	2	500	2.5	0.5	600	12	1.5	1000	6.7						
9	1	300	3	1	600	6	1.5	1000	6.7						
10							1.5	1000	6.7						
11							1.5	1000	6.7						
12							1.5	1000	6.7						
13							1.5	1000	6.7						
14							1.5	1000	6.7						
15							1.5	1000	6.7						
mean	1.1	517	6.2	1	600	7	1.5	1000	6.7	1.4	870	6.5	2	5000	25

4.4: Bambara Groundnut Yields

Yields of Bambara Groundnut Obtained by Farmers during a Normal Agricultural Year and for 2015/2016 crop (during a drought period)

Table 4 summarizes the ranges of yields obtained by farmers at each village during a climatically normal year as well as from the 2015/2016 cropping season, which was cultivated during a severe drought period; farmers also felt that this year was the most severe drought that they had experienced for a long time. Details of the yields obtained by the farmers at each village are shown in Table 5 (Details on how the yields were calculated can be found in Chapter 3.6.3). During a normal agricultural year, the farmers without irrigation (Ga Ramphere, Makatiane and Ga Mogano) obtained yields between 160-333kg/ha. During the drought year of 2015/2016 these farmers experienced yields losses between 50-90% reduction and obtained yields of between 20-100kg/ha. The farmers at Ga Molepo, who used drip irrigation for their Bambara groundnut, obtained yields of 500kg/ha during a normal climatic year and 600kg/ha during the drought year of 2015/2016. At Perskebult, the farmers had access to furrow irrigation; during a normal climatic year and the drought year of 2015/2016 they would obtain yields between 80-267kg/ha. The availability of irrigation was the largest factor to influence Bambara groundnut yields, particularly during the drought period. However, other factors such as planting method, soil fertility, availability of fertilizers and the type of irrigation (i.e. furrow or drip) would also have significantly influenced Bambara groundnut yields and explains why the farmers at Perskebult obtained low yields during a normal climatic year compared to the farmers in other villages. This will be discussed further in the analysis (Chapter 5). All farmers agreed that Bambara groundnut was the least affected plant by the drought. Also, during the drought year of 2015/2016, while farmers with access to irrigation experienced yield losses of maize, groundnut and cowpea, most farmers without irrigation experienced complete crop failure of maize, cowpea and groundnut.

Table 4: Overview of Bambara Groundnut (BGN) Yields Obtained by Farmers During a Normal Climatic Year and During a Drought Period (2016)

	Village				
	Perskebult	Ga Ramphere	Makatiane	Ga Mogano	Ga Molepo
Access to irrigation	Yes	No	No	No	Yes
Cropping Method	Intercropping	Intercropping	Intercropping	Intercropping	Sole Crop
Area allocated to BGN (m^2) (range)	300-1250	600	1000	600-1250	5000
% Land allocated to BGN (range)	3%-9%	3%-12%	7%	5%-8%	25%
BGN Production range (kg)	4-15	12-20	40	12-20	250
BGN Production range (kg/ha)	80-267	200-333	200	160-229	500
2016 Yields (kg) (range)	4-15	4-6	4	3-4	300
2016 Yield (kg/ha) (range)	80-267	67-100	20	32-67	600

Table 5: Bambara Groundnut Yields Obtained by The Farmers During A Normal Climatic Year and During a Drought Period (2016)

	Village									
	Perskebult (furrow irrigation)		Ga Ramphere (no irrigation)		Makatiane* (no irrigation)		Ga Mogano (no irrigation)		Ga Molepo* (drip irrigation)	
Farmer Number	Normal Yields Obtained (kg/ha)	Yields Obtained During Drought Period (kg/ha)	Normal Yields Obtained (kg/ha)	Yields Obtained During Drought Period (kg/ha)	Normal Yields Obtained (kg/ha)	Yields Obtained During Drought Period (kg/ha)	Normal Yields Obtained (kg/ha)	Yields Obtained During Drought Period (kg/ha)	Normal Yields Obtained (kg/ha)	Yields Obtained During Drought Period (kg/ha)
1	120	120	333	67	200	20	160	32	500	600
2	89	89	233	83	200	20	250	38	500	600
3	250	250	200	67	200	20	229	43	500	600
4	250	250	333	67	200	20	200	40	500	600
5	267	267	267	83	200	20	200	67	500	600
6	125	125	200	67	200	20				
7	167	167	200	67	200	20				
8	80	80	300	83	200	20				
9	167	167	200	100	200	20				
10					200	20				
11					200	20				
12					200	20				
13					200	20				
14					200	20				
15					200	20				
mean	168	168	252	76	200	20	208	44	500	600

*The farmers at Ga Molepo and Makatiane provided group responses to the questions related to Bambara groundnut yields.

4.5: Pests and Diseases which affect Bambara Groundnut Production, Encountered by Farmers

Viruses and Diseases That Affected Bambara Groundnut

All the farmers stated that they have not encountered any viruses or diseases that affect their Bambara groundnut crops.

Pests Encountered by Farmers that affect Bambara Groundnut whilst in the Field

Pests that were known to affect Bambara groundnut in the field included termites, birds and cutworms (See Table 6). The Agricultural Extension Officers present during the interviews believe that the birds that reportedly ate Bambara groundnut during the harvesting and planting season, were guinea fowl (Mrs P Makwela, *pers.comm*. June 2016). The farmers believed that scarecrows had no effect on the birds and the farmers who perceived the birds as a significant pest felt that they were too old and not mobile enough to scare away the birds themselves. Some of the farmers used to acquire the help of children to scare away the birds, however this strategy was no longer possible because the children had to go to school. According to the farmers, the birds appeared to have a stronger impact on Bambara groundnut production in the villages Makatiane and Ga Mogano compared to the other villages (See Table 15). This suggests that location may have influenced the affect birds had on Bambara groundnut production.

Pests Encountered by Farmers that affect Bambara Groundnut during the Storage of Bambara Groundnut

The only pest described by the farmers that affected Bambara groundnut during storage was weevil. Overall, weevils were considered a minor pest due to the pest control methods (discussed later) used during storage of Bambara groundnut. The farmers felt that only deshelled Bambara groundnut seeds were susceptible to weevil attack.

4.6: Farmers Preservation and Storage Methods of Bambara Groundnut

Fresh Bambara groundnut had to be consumed within two weeks of harvesting the crop, in order to prevent the seed from rotting. To store Bambara groundnut seed for longer, either for future consumption of for planting the following season, the seeds were dried in the sun for 1-2 days within a two week period of harvesting the seed. When possible, farmers would store dried Bambara groundnut with their shells intact to prevent weevil infestations. Dried Bambara groundnut seeds that had their shells intact were stored in jute bags. Seeds with either damaged or moist shells were completely de-shelled and the seeds/nuts stored in sealed plastic containers to mitigate weevil damage. All Bambara groundnut was covered in wood ash to deter weevil and mitigate damage to the seed.

Table 6: Pests Encountered By Farmers Which Effected Bambara Groundnut Whilst It Was In The Field and During Storage

Village	Pests encountered in the field	Prevention Strategy	Impact of Pest on Yields	Additional Notes
Perskebult	None	NA	NA	
Ga Ramphere	Termites	Crop rotation	low	Termites would cause a minor loss of yields during years with low rainfall
Makatiane	Birds	None	High	Pheasants and Guineafowl ate seeds before germinating during planting and whilst harvesting. Yield losses due to attacks from Pheasants and Guineafowl were considered to be a major problem for farmers.
	Termites	Crop rotation	medium	Termites would cause a minor loss of yields during years low rainfall
Ga Mogano	Birds	None	High	Same as above
	cutworms	Crop rotation	medium	
Ga Molepo	None	NA	NA	NA

Village	Pests encountered during Storage	Prevention Strategy	Impact of Pest on Yields	Additional Notes
All villages	Weevil	Maintain shells on Bambara groundnut when Possible. Deshelled Bambara groundnut placed in sealed container Moist Bambara groundnut deshelled and placed in plastic container.	low	Providing the correct storage methods were implemented, weevil was not considered a major pest issue

4.7: Farmers Preferences and Patterns for Consumption of Bambara Groundnut

Farmers' preferences for consumption of Bambara groundnut was to eat it whilst fresh. Fresh Bambara groundnut seeds took 40 minutes to 1 hour to boil and was normally eaten on its own as a snack and sometimes used to make 'knorx' soup. Dried Bambara groundnut was regarded as having a much less desirable taste and took considerably longer to cook (boiling time of 3-4 hours). After boiling the dried Bambara groundnut, they are mixed with samp and eaten as a porridge or starch.

The highest consumption of Bambara groundnut occurred during the months March-June when it could be consumed fresh (see Table 7). It was commonly stated that farmers would consume Bambara groundnut as often as possible whilst it was fresh and many farmers were inhibited from consuming more fresh Bambara groundnut due to the limited amount available.

After June, farmers reduced their consumption of Bambara groundnut because only dried Bambara groundnut was available and this was considered to be much less tasty than fresh Bambara groundnut and took a significantly longer time to cook. During the planting season for Bambara groundnut (i.e. the end of October to December), the farmers reduced their consumption of Bambara groundnut and prioritized their seed reserves for planting. After the planting season ends, all farmers would normally stop consuming Bambara groundnut, either because they had completely run out of seed, or because they had reserved the remaining seed for the following planting season, in case the current crop was very poor. The farmers' consumption of Bambara groundnut normally resumes during the next harvesting season, which is normally March.

Table 7: Farmers Consumption Pattern Throughout Year of Bambara Groundnut

	Month											
Number of portions consumed*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
One everyday				4	4	4						
4-6 times a week				5	5	5	5					
2-4 times a week			5	10	10	10	25	5	5			
Once a week			9	24	24	24		5	5	5		
Once every 2 weeks												
Once every 2 -4 weeks							13	33	33	16	16	16
Less than once a month												
Not at all	43	43	29							22	27	27

*One portion approximately equated to a handful of Bambara groundnut

4.8: Use of Bambara Groundnut as a Cash Crop and Marketing of Bambara Groundnut Purpose of Bambara Groundnut Production

Overall, during a normal agricultural year, 25 out of the 43 (58% of) farmers interviewed produced Bambara groundnut for household use only, 13 (30% of) farmers produce Bambara groundnut for mostly household use but also sell some as a cash crop, and only five (12% of) farmers (i.e. all from Ga Molepo) produce most of their Bambara groundnut to sell (See Table 8). The 25 farmers who produced Bambara groundnut for household purposes only consisted of all the farmers from Makatiane (15 in

total) and Ga Mogano (five in total), as well as five of the nine farmers interviewed from Ga Ramphere. Overall 80% of these farmers felt that the yields obtained for Bambara groundnut were too low and they could only produce enough for household purposes (see Table 9). A low demand for Bambara groundnut was given as a reason by 20% farmers, all of which were situated at Ga Ramphere. From Table 8 it can be seen that there was a reduction in the number of farmers who sold Bambara groundnut compared to during a normal climatic year. The farmers who stopped selling Bambara groundnut during the drought period had no access to irrigation, which caused significant yield reductions, forcing them to produce for household purposes only.

All farmers in this study only sold fresh Bambara groundnut and no dried Bambara groundnut was sold. Fresh Bambara groundnut was sold in quantities of 500g, 1kg, 2kg, 5kg and 10kg. Fresh Bambara groundnut was considered to taste better than cowpea and groundnut and was considered a delicacy by most farmers. The farmers believed that there was no market for dried Bambara groundnut since the locals would rather purchase cowpea and groundnut instead. The reasons why locals preferred to purchase groundnut and cowpea compared to dried Bambara groundnut were because a) It took a long time to cook dried Bambara groundnut compared to other legumes; b) Dried Bambara groundnut had a less desirable taste; c) Cowpea and groundnut price was lower than dried Bambara groundnut.

Table 8: Purpose of Bambara Groundnut Production

	Normal purpose of Bambara groundnut production			Purpose of Bambara groundnut production during drought period		
	Household use Only	Mostly for household but sell some	Mostly to sell	Household use only	Mostly for household but sell some	Mostly to sell
Number of Farmers	25	13	5	29	9	5
%	58%	30%	12%	67%	21%	12%

Table 9: Main Reasons Why Farmers Who Only produced Bambara Groundnut for Household Purposes (25* out of 43 Farmers Interviewed) Did Not Sell The Crop

Reason	Number of Farmers	Percentage
Lack of Markets	5	20%
Yields too low	20	80%

*The 25 farmers included 15 from Makatiane, five from Ga Mogano and five from Perskebult

Marketing of Bambara Groundnut

Farmers only sold freshly harvested Bambara groundnut between the months March-June and all sales occurred locally, with farmers selling Bambara groundnut either from their own houses or at the local village market. The exception was the farmers at Ga Molepo, who also sold Bambara groundnut at the nearby town of Mankweng. The Agricultural Extension Officers based at Mankweng buy Bambara groundnuts from these farmers who visit the office annually to sell their Bambara groundnut. The price of fresh Bambara groundnut, groundnut and cowpea were R25-35/kg, R15-20/kg and R20-25/kg respectively (see Table 10). The farmers at Ga Molepo were able to sell their Bambara groundnut for a higher price compared to the farmers at any other sites visited. According to the Agricultural Extension Officers (Mrs M Cate and Mrs P Makwela, *pers.comm*. June 2016) the farmers at Ga Molepo had a good reputation for producing good quality Bambara groundnut. This was likely why the farmers at Ga Molepo were able to sell Bambara groundnut at a higher price than the other farmers.

Table 10: Selling Price of Bambara Groundnut, Groundnut and Cowpea to Local Markets

Legume	Perskebult (R/kg)	Ga Ramphere (R/kg)	Makatiane (R/kg)	Ga Mogano (R/kg)	Ga Molepo (R/kg)
Bambara Groundnut	25-30	25-20	25-30	25-30	30-35
Cowpea	20-25	20-25	20-25	20-25	20-25
Groundnut	15-20	15-20	15-20	15-20	15-20
Cereal Crop					
Maize	22	22	22	22	22

Farmers' perceptions of the supply and local demand for Bambara groundnut, and farmers' Selling Price of Bambara groundnut

During the March-June period when fresh Bambara groundnut was sold, 79% of farmers interviewed believed that the local demand exceeded supply, whilst 21% of farmers believed that the supply of fresh Bambara groundnut was greater than demand (see Table 11). All farmers who thought that the supply of Bambara groundnut was greater than local demand were all from Ga Ramphere, with these farmers stating that they produced a surplus (i.e. more than their own village can consume). This is because many of the inhabitants of this village all grow Bambara groundnut and so they each consume their own, leaving little/no opportunity for the farmers to sell to local people.

Table 11: Farmers Perceptions of The local Supply and Demand of Bambara Groundnut

	Village						
Supply and Demand Ratio	Perskebult	Ga Ramphere	Makatiane	Ga Mogano	Ga Molepo	Total	%
Demand Significantly Greater Than Supply	9				5	14	33%
Demand Greater Than Supply			15	5		20	47%
Supply and Demand Equal							0%
Supply Greater Than Demand		2				2	5%
Supply Significantly Greater Than Demand		7				7	16%

4.9: Farmers Prediction of Their Future Production of Bambara Groundnut

While only 12% of farmers wanted to increase Bambara groundnut production in the future, 53% of farmers were going to maintain the same Bambara groundnut production and 35% will probably likely decrease Bambara groundnut production (See Figure 3). The farmers who wanted to increase production were from Ga Molepo and each farmer had bought an extra 0.5ha of land. All this extra land was being dedicated to Bambara groundnut to double production levels. Ga Molepo was one region where demand reportedly outstripped supply and they felt that selling the crop was profitable. It must be highlighted that the farmers at Ga Molepo had a larger catchment area for selling Bambara groundnut compared to the other farmers (further details are provided in Chapter 4.8). The 35% of farmers who said that they would likely decrease production had problems with soil fertility and were reducing their production of all crops including Bambara groundnut.

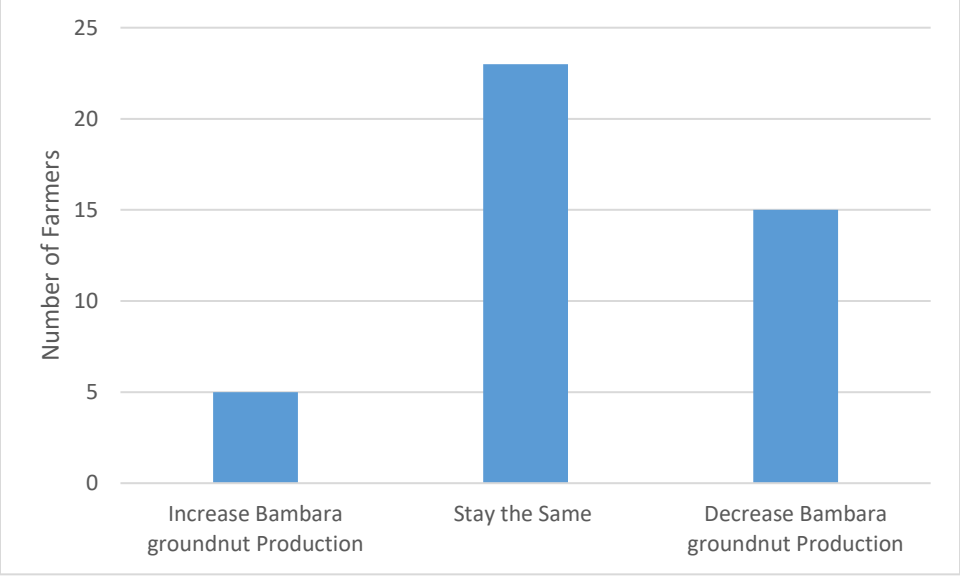

Figure 3: Farmers Future Intentions for Bambara Groundnut Production

4.10: Farmers' Comparative Assessment of the legumes, Bambara Groundnut, Cowpea and Groundnut

It can be seen from Table 12 that compared to cowpea and groundnut, Bambara groundnut was regarded by the farmers to be:

a) The most drought resistant legume

b) The most resistant to pests both in the field and during storage

c) The most nutritional crop

d) The highest price per kg that farmers would receive from selling the produce

e) The tastiest crop whilst fresh.

All farmers also agreed that Bambara groundnut:

a) Was the lowest yielding legume

b) Was the most susceptible to water logging

c) The farmers at Ga Molepo, who had access to irrigation, believed that Bambara groundnut had the highest demand and was the most profitable legume.

The farmers from the other villages however believed that Bambara groundnut was the least profitable legume because of the crop's low yields. These farmers also thought that Bambara groundnut had the lowest demand out of the three legumes and this was mainly due to low demand of mature Bambara groundnut.

Table 12: Farmers Ranked Performance of Legumes Bambara Groundnut, Cowpea and Groundnut

		Factor											
Farming Communities	Legume	Drought resistance	Resistance to pests and disease in field	Resistance to Pests and Disease During Storage	Crop Yields	Susceptibility to Waterlogging	Price per Kg of crop	Demand for crop	Profitability of crop	Perceived nutritional value	Taste fresh	Taste mature	Total Rating
Perskebult, Ga Ramphere, Makatiane, Ga Mogano, Ga Mogano	Bambara Groundnut	1	1	1	3	3	1*	3	3	1	1	2	19
	Groundnut	3	2	2	2	2	3	1	1	3	3	3	25
	Cowpea	2	3	3	1	1	2	2	3	2	2	1	22
Ga Molepo	Bambara Groundnut	1	1	1	1	3	3	1*	1	1	1	2	15
	Groundnut	3	2	2	2	2	2	3	2	3	3	3	27
	Cowpea	2	3	3	3	1	1	2	3	2	2	1	20

* Price per kg of fresh Bambara groundnut

4.11: Farmers' Perceptions of the Enabler and Barriers to Bambara Groundnut Production

Table 13 shows the farmers' scoring of enablers to Bambara groundnut production and Table 14 shows the main enabler each farmer gave for growing Bambara groundnut. The enablers considered most important by farmers for Bambara groundnut production were associated with the role Bambara groundnut plays in the household diet. In particular, farmers perceived Bambara groundnut as a healthy and nutritious food source and farmers liked the taste of Bambara groundnut. All farmers believed that Bambara groundnut was an effective partner crop for maize production and an important enabler perceived by all farmers were associated with Bambara groundnut's nitrogen fixing capability and the legume's ability to improve soil fertility. Farmers who intercropped Bambara groundnut with maize said that it reduced weeding time, improved land use efficiency, helped retain soil moisture levels and reduced soil erosion, and overall, these farmers considered these factors together as important enablers. Other commonly perceived minor enablers for Bambara groundnut production were that the crop stores well having good resistance to pests during storage, the crop has a good drought tolerance, its use as animal feed and its perception as a traditional crop. Further details of the farmers perceived enablers to Bambara groundnut production will be discussed in Chapter 5.3.1 of the Analysis chapter.

From Table 15 and Table 16, it can be seen that the most important barriers perceived by farmers for Bambara groundnut production were:

a) Bambara groundnut is a low yielding crop, particularly compared to other grain legumes

b) A lack of available farmland

c) A lack of irrigation (from those farmers without irrigation).

Barriers that appeared to be important to certain villages, but were overall considered minor barriers to Bambara groundnut production were:

a) Poor market access

b) Low soil fertility

c) Labour intensive crop/labour constraints

d) Field pests effecting Bambara groundnut

e) Susceptibility to waterlogging.

These barriers will be discussed in more detail in the Analysis Chapter.

Table 13 Farmers Reasons For Bambara Groundnut Production

	Village				
	Perskebult	Ga Ramphere	Makatiane	Ga Mogano	Ga Molepo
Traditional Crop	3	2	2	2	3
Good Taste	5	4	5	5	5
Nutritious	5	5	5	5	5
Cash Crop	5	2.78	1	1	5
High Market Value	1.74	3	1	1	5
Pest Resistance (in field)	2.86	2	1	1	5
Pest Resistance (During Storage)	3	3	3	1	3
Effective Intercrop	4	3	2.2	3	*
High Drought Resistance	2.439	2	2	2.2	3
Nitrogen Fixator/improves soil fertility	2	2	2	3	5
Medicinal purposes	1.14	1	1	1	1
Animal Feed	1	2	2	2	2

* The farmers at Ga Molepo only planted Bambara groundnut as a sole crop and did not respond this question

Table 14: Farmers Main Enabler For Bambara Groundnut Production

	Number of Farmers From Each Village					
	Perskebult	Ga Ramphere	Makatiane	Ga Mogano	Ga Molepo	total
Traditional Crop						
Good Taste			2			2
Nutritious	3	5	9	5		22
Cash Crop	4	4			5	13
High Pest Resistance						
Effective Intercrop	2		4			6
High Drought Resistance						
Nitrogen Fixator						
Medicinal purposes						
Animal Feed						
total	9	9	15	5	5	43

Table 15: Weightings of Barriers Given by Farmers for Bambara Groundnut Production

	Village					
	Perskebult	Ga Ramphere	Makatiane	Ga Mogano	Ga Molepo	Mean
Land Availability	5	5	5	5	5	5
Low Yield/Lack of Improved Varieties	5	4	5	5	3	4
Lack Of Irrigation	1	5	5	5	1	3
Poor Market Access	1	5	2	1	1	2
Poor Market Price	1	2	2	1	1	1
Low demand by household members	1	2	1	1	1	1
Poor soil fertility	2	1	4	2	1	2
Lack of credit	4	1	2	3	1	2
Pests (in field)	1	2	4	4	1	2
Pests (During Storage)	1	1	1	2	1	1
Susceptible to Water Logging	2	3	2	1	1	2
Labour intensive crop/labour constraints	4	2	2	1	1	2
Tractor Does not Plough Deep Enough (Management)	1	5	1	1	1	2

Table 16 Farmers main Barrier Perceived to Bambara Groundnut Production

	Number of Farmers from Each Village					
Major Barrier	Perskebult	Ga Ramphere	Makatiane	Ga Mogano	Ga Molepo	Total
Low Yields/ Lack of improved cultivars	4	0	4	0	0	8
Lack of Irrigation	0	0	3	3	0	6
Poor management practices	0	0	1	0	0	1
Poor market access	0	9	0	0	0	9
Poor soil fertility	0	0	2	0	0	2
Lack of credit	2	0	0	2	0	4
Pests during storage	0	0	4	0	0	4
Susceptibility to Water Logging	0	0	0	0	0	0
Lack of Available Land	*	*	*	*	5	5
Labour constraints	3	0	1	0	0	4
Total	9	9	15	5	5	43

*These farmers were prohibited from answering a lack of available land as their main barrier to Bambara groundnut production because they only allocated a small amount of their land to Bambara groundnut production

4.12: Bambara groundnut Landraces Cultivated by Farmers

In total, eight different landraces were identified at the 5 sites (shown in Figure 4). Seven of the 8 landraces were observed in all five villages and the eighth landrace identified was only used at Ga Molepo. Farmers perceived the different landraces to have both positive and negative traits. Black seeds (#4) were considered to be early maturing which was seen as a positive trait of the crop; however the seeds were often smaller which was considered negative. The red seeds (6) were late maturing, but they often produced large seeds and were considered a good yielder. The brown/black eye (1), brown (2) and cream with black eye (5) seeds were considered to produce reasonably good yields with medium to large size kernels. Farmers showed no preference for the taste of different Bambara groundnut and those that sold fresh Bambara groundnut, did so in bags containing randomly mixed landraces. Some of the farmers mentioned that when they ran out of Bambara groundnut seeds for planting they obtained Bambara groundnut seed from other farmers.

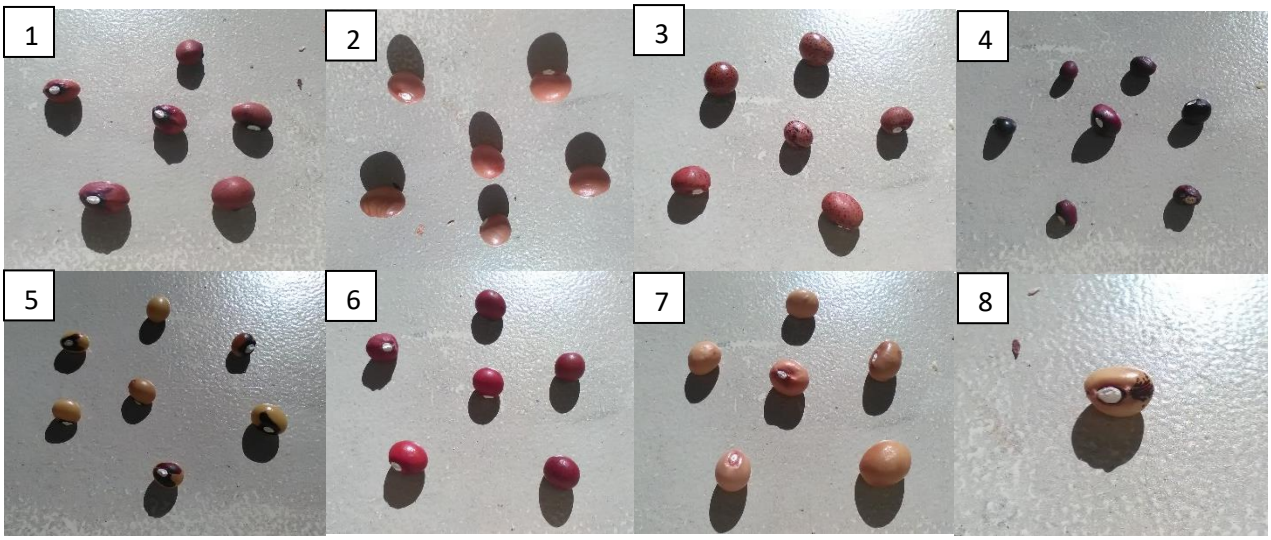

Figure 4 – Pictures of the 8 different landraces of Bambara groundnut identified in this study. From top Left to bottom right: (1) brown/black eye (2) brown (3) Brown/Black speckles (4) black, (5) Cream/black eye (6) red (7) Cream (8) Cream/Black Speckles

4.13: Frequency of Agricultural Extension Officer visiting Farmers

It was reported by the Agricultural Extension Officers that they normally visited the farmers interviewed in this study once a month. During cases of emergencies, such as during the drought period when interviews had occurred, the Agricultural Extension Officers were required to visit the farmers three times a month. The extension officers were aware that there were still a large number of farmers who received very little/no support from extension officers and still cultivated Bambara groundnut using traditional practices. Most of these farmers were believed to live in the more isolated regions of the Capricorn District, rather than near the city of Polokwane. It was also stated by an extension officer that, where farmers were practicing Bambara groundnut production in isolated areas, there were cultural beliefs that influenced its production. These cultural beliefs will be further discussed in the analysis (Chapter 5).

Chapter 5: Analysis

5.1: Introduction

Chapter 5.2 will discuss the farmers' demographics, the farmers' production and utilisation of Bambara groundnut and agronomic practices used by the farmers. Chapters 5.3 and 5.4 will assess the farmers' perceived enablers and barriers to Bambara groundnut production, using the qualitative evidence provided by the farmers (as summarised in Tables 13-16). Chapter 6 provides a summary of findings and assesses the future potential for Bambara groundnut to benefit farmers' food and economic security.

5.2: Farmers Utilisation of Bambara Groundnut

Farming Communities, Farmers Demographics and Key Elements of Farming strategy

All farmers interviewed in this study were small scale farmers, who are the primary producers of the Bambara groundnut crop in South Africa (Swanevelder 1997; DAFF 2016). The farming communities who were interviewed in this study had similar demographics compared to the demographics of small scale farmers in South Africa. In South Africa, approximately 80% of small scale farmers own between 0-2ha (Pienaar 2013) and according to Oni et al. (2012) the average farm sizes for small scale farmers in South Africa was approximately 1.5ha, which is comparable to the results obtained from this study. The results indicate that in South Africa, most farmers who cultivate the crop were female. In Limpopo province 80% of small scale farmers were women (Oni et al. 2012), which is roughly the same proportion of female farmers interviewed in this study. The findings align with several other studies which state that Bambara groundnut production was mostly produced by female farmers (De Kock Undated; Greenhalgh 2000; Mkandawire and Sibuga 2002; Bamshiye et al. 2011).

The majority of farmers interviewed (72%) were above the age of 60, and most of the farmers interviewed were retirees who were farming to subsidize their pension. The results appear to indicate that Bambara groundnut is mostly cultivated by relatively old men and women. It has been highlighted

by Pienaar (2013) stating that, in the former homelands of South Africa, the population of the smallholder farming population is ageing. Unless farmers are able to pass on their indigenous knowledge to a younger generation of farmers, then much of this knowledge may be lost for future farmers to utilize.

Farmer's prioritization of Bambara groundnut, purpose of farming and plot size allocated to Bambara Groundnut Production

The study found two distinct groups of Bambara groundnut producers, in terms of the scale of Bambara groundnut production as well as their purpose for cultivating the crop. The largest group of Bambara groundnut producers, consisting of the farmers from Pesksbult, Ga Ramphere, Makatiane and Ga Mogano, utilized Bambara groundnut within the context of how Swanevelder (1998) and DAFF (2016) describe Bambara groundnut production in South Africa. These farmers considered Bambara groundnut as the third most important grain legume, after groundnut and cowpea, in terms of plot size allocated to the crop. Swanevelder (1998) and DAFF (2016) describe Bambara groundnut as the third most important grain legume for small scale farmers in South Africa, which aligns with the findings from this study. The 'Bambara Groundnut Production Guide' produced by the South Africa's Department of Agriculture Forestry and Fisheries states that the size of Bambara plots ranges from 300 to 2500 m^2 per farmer (DAFF 2016), which is within the range of plot sizes used by this group of farmers. All these farmers produced Bambara groundnut for predominantly own household purposes, which also confirms other studies (Swanevelder 1998; DAFF 2016). This is also the main purpose reported for producing the crop in all other main Bambara groundnut producing countries in Africa (Heller 1997; Greenhalgh 2000; Bamshaiye et al. 2011; Hillocks et al. 2012).

The farmers at Ga Molepo cultivated Bambara groundnut on a larger scale compared to farmers in other areas, with plot sizes double the high-end range of plot sizes cultivated by small scale farmers, according to DAFF (2016). Bambara groundnut was more highly prioritized by the farmers at Ga Molepo and was their second most important cash crop after maize. According to DAFF (2016) it is only in recent years that farmers in South Africa have started to sell Bambara groundnut, albeit on a small scale. Swanevelder (1997) stated that farmers in South Africa had shown very little interest in the commercial production of the crop, although he believed that this situation was changing. The results from this research indicate that almost all of the farmers are interested in selling the crop, with many of them already selling Bambara groundnut, adding credence to Swanevelder's (1997) observations. The farmers at Ga Molepo show that newly emerging farmers are utilising Bambara groundnut and producing it on a much larger scale, with motives much more commercially orientated compared to previous farmers. Due to the small sample size however, it is difficult to determine whether this is a one-off example or is a trend happening elsewhere.

Agronomic Practices of Bambara Groundnut

All the farmers were cultivating Bambara groundnut in accordance to the Agricultural Extension officers and to the best known Bambara groundnut practices in South Africa (DAFF 2016). Only the farmers at Ga Molepo presoaked the seed for 24 hours before planting, in order to improve seedling emergence and

establishment. Presoaking the seeds 24-48 hours before planting significantly improves emergence rate of seedlings, which consequently enhances yields (Berchie et al. 2010b). The presoaking of seeds was not a practice recommended by the Agricultural Extension Officers, nor is it mentioned in South Africa's DAFF Bambara Groundnut Production Manual (DAFF 2016). It is therefore likely that many other Bambara groundnut producers are not presoaking the seeds prior to planting and many other agriculture extension officers are not advising farmers to use this agronomic practice because they are not aware of this agronomic practice. This is a cheap and simple practice which could be easily tested by the farmers themselves and could potentially improve their yields.

All farmers in this study were planting unimproved, locally derived landraces, and farmers had no access to improved landraces or high yielding accessions. The lack of improved varieties of Bambara groundnut has been highlighted as an important production constraint to this crop (Azam-Ali et al. 2004; Fleissner 2006; Pungulani et al. 2012; Mohammed 2014). It was evident that the farmers planted a mixture of landraces to improve yield stability, which is a common strategy practiced by farmers living in marginal environments (Vincent et al. 2010; Abu and Buah 2011; Ouedraogo et al. 2011). Whilst planting a mixture of landraces is a lower risk strategy for farmers in hostile and unpredictable environments, since part of the seed population is likely to survive, this strategy will also limit the maximum yields obtainable (Massawe et al. 2005). For the farmers without assess to irrigation it is most likely beneficial for the farmers to continue cultivating a mixture of landraces. For the farmers at Ga Molepo and Perskebult, who have access to irrigation, it may be beneficial for them to focus on cultivating a few selected Bambara groundnut accession that are known to have potentially high yields such as reported for the red or cream Bambara groundnut landrace.

It appears that no selection of Bambara groundnut for planting in the following year was conducted. If farmers ran out of seed they would purchase seed from other farmers, which was also commonly found practices of farmers in Ghana (Vincent et al. 2010). For most farmers interviewed, Bambara groundnut was only seen as a minor element of their livelihood strategies and all of these farmers were resource constrained. Therefore improving yield varieties was not of high importance for many of the farmers, who were more largely focused on maize. Selection of seed is necessary to develop higher yielding landraces of Bambara groundnut (Massawe 2005). Once improved Bambara groundnut landraces become available, there may be opportunities to support farmers in generating higher yields of Bambara groundnut.

Bambara Groundnut Yields

The range of yields reported by farmers in this study was 80-600kg/ha, and the mean was 402kg/ha, which is comparable to the findings from other studies reporting yields of Bambara groundnut obtained by small scale farmers in other African countries (Heller et al. 1997; Fleissner 2006; Hillocks et al. 2012; Akpalu et al. 2013; Alhassan and Egbe 2013b). Whilst there are published results for Bambara groundnut yields obtained in South Africa (Swanevelder 1998; Sinefu 2011; Mabhaudhi et al. 2013) the data was obtained from controlled field experiments that do not reflect the growing conditions experienced by small scale farmers interviewed in this research.

The main factors that affected Bambara groundnut yields were: a) access to irrigation; b) soil fertility and access to fertilizer; c) method of planting (sole or intercropped). Whilst Bambara groundnut is

considered to have high drought resistance compared to other crops, yields are highly affected by water stress and even moderate water stress can cause high yield losses (Mwale et al. 2007; Sinefu 2011; Mabhaudhi et al 2013; Shareef et al. 2013; Chai et al. 2016). Access to irrigation had the largest influence on Bambara groundnut yields, in particular during the drought period. A lack of irrigation was considered to be one of the most important barriers to Bambara groundnut production, which will be discussed further in Chapter 5.3.2. All farmers except the farmers at Perskebult used fertilizer on Bambara groundnut, which explains why these farmers had significantly lower yields compared to the other farmers. It was found in this study that farmers who intercropped Bambara groundnut obtained on average 60% lower yields per hectare compared to farmers who sole cropped Bambara groundnut. Whilst the farmers who sole cropped Bambara groundnut also had access to irrigation (which explains most of this difference in yields) the planting method would have also affected Bambara groundnut yields. Several field studies have found significant yield reductions in Bambara groundnut yields when intercropped with maize compared to when grown as a pure stand, with studies reporting a 70-95% reduction in Bambara groundnut yields (Friesen and Palmer 2004; Jacob et al. 2014; September 2015; Mkandawire et al. 2016). Whilst Bambara groundnut yields were lower when intercropped with maize, the farmers felt that the maize/Bambara groundnut combination worked well and was overall considered the 3rd most important enabler for planting the crop (See Table 13). Therefore for most farmers, the benefits of intercropping Bambara groundnut with maize far outweighed the yield losses of Bambara groundnut created from the cropping combination.

Farmers Consumption of Bambara Groundnut

Most consumption of Bambara groundnut occurs during the months April to June, which is the harvesting season for Bambara groundnut (See Table 7). The results align with Greenhalgh (2000) that fresh Bambara groundnut are often the most preferred method of consumption. Between April-June most farmers consumed Bambara groundnut between 2-7 times a week, which indicates that during this period, Bambara groundnut plays an important role in farming households' nutrition. For the rest of the year however, farmers rarely consume Bambara groundnut.

Supply and Demand for Bambara Groundnut and Selling Price of Bambara Groundnut

This study found that the majority of farmers believed that fresh Bambara groundnut was highly popular, with local demand being higher than supply. In several other African countries it is also common for fresh Bambara groundnut to be highly popular in the local regions where grown, with demand outstripping supply (Greenhalgh 2000; Mkandawire, 2007; Hillocks et al. 2012). According to Swanevelder (1998) there is a constant shortage of Bambara groundnut in South Africa. In this study, all farmers were able to obtain higher prices for fresh Bambara groundnut compared to other legumes (See Table 9), with prices ranging between R25-35/kg. In 1998 Swanevelder (1998) reported that in South Africa Bambara groundnut was being sold for up to R20/kg; after taking inflation into account the prices that farmers quoted in this study sound reasonable. Greenhalgh (2000) stated that fresh Bambara groundnut is often sold at a premium compared to other legumes, which aligns with the findings found in this study. It was found that the farmers at Ga Molepo could obtain higher prices of Bambara groundnut (R30-35/kg) compared to the other areas (where Bambara groundnut was sold for 25-

R30/kg). The farmers at Ga Molepo were the largest producers of Bambara groundnut in the region according to an agricultural extension officer (Mrs M Cate 2016, *pers.comm*, June). The researcher felt that the farmers at Ga Molepo were highly reputable for Bambara groundnut production within their local community and were the 'go-to' people to buy Bambara groundnut from, which enabled them to sell Bambara groundnut at a higher price compared to other farmers. Overall, the combination of high local demand perceived by farmers for Bambara groundnut, and the high price they could acquire from selling the crop indicates that there is high potential for more fresh Bambara groundnut to be sold within the villages. It was found however that at Ga Ramphere, demand for Bambara groundnut was low, indicating that not all farmers would be able to sell more Bambara groundnut and would depend on the village where they reside.

In this study, it was found that none of the farmers sold dried Bambara groundnut. Greenhalgh (2000) reports that dried Bambara groundnut was sold in South Africa, however it is believed that a large proportion of the market was supplied from imports from Zimbabwe. This is because it was cheaper for traders to purchase Bambara groundnut in Zimbabwe; however this may have changed as the production costs in Zimbabwe were likely to have increased (Greenhalgh 2000). The reasons stated by farmers for not selling dried Bambara groundnut are similar to constraints in other African countries, such as the long cooking time of dried Bambara groundnut (Berchie et al. 2010a; Adzawla 2016a). In this study, most Bambara groundnut was utilised whilst fresh and little was used in its dried state. Therefore, the additional barriers perceived for dried Bambara groundnut were not a major concern to the farmers in this study; however if production significantly increased then these barriers may become an important issue.

Marketing of Bambara groundnut

According to DAFF (2016), there are no formal markets for Bambara groundnut (DAFF 2016). The results from this study support this and it appears as though all sales of Bambara groundnut are informal through local markets. For most farmers, the lack of formal markets was not hindering their ability to sell Bambara groundnut, since the demand for fresh Bambara groundnut exceeded supply in their local markets. Most farmers preferred to sell their produce through local markets because they were able to obtain higher prices for their produce. The farmers at Ga Ramphere however would have preferred the option to sell Bambara groundnut formally because local supply of Bambara groundnut was higher than demand and they were not able to sell all of their Bambara groundnut. It is unlikely that the farmers at Ga Ramphere are an isolated example of farmers struggling to sell fresh Bambara groundnut due to the lack of marketing opportunities. Furthermore if farmers were able to obtain higher yields of Bambara groundnut, it may not be long until their local markets become saturated. Therefore, in order to support small scale farmers with Bambara groundnut production in the long term, many farmers would benefit from the establishment of formal markets.

5.3: Common Enablers and Barriers of Bambara Groundnut Production

5.3.1: Enablers

Bambara Groundnut considered a Healthy and Nutritious Food Source by the Farmers

The perception that Bambara groundnut was considered a healthy and nutritional food source was considered as an enabler of most importance (scoring 5 out of 5) and 51% of farmers believed that this was the most important reason for producing the crop (See Tables 13 and 14). Farmers regarded Bambara groundnut as nutritionally superior to both cowpea and groundnut (See Table 12).

Whilst the farmers were often not specific about the nutritional benefits of consuming Bambara groundnut, they explained how the crop makes them feel and their uses for Bambara groundnut. All farmers believed that Bambara groundnut was a good source of protein and felt that it complemented their maize based diets. During discussions with farmers, it was evident that whilst meat was not uncommon in most farmer's diets, most protein was obtained from plant sources of which a large proportion was obtained from the legumes they produce such as Bambara groundnut. It was therefore evident that Bambara groundnut acted as a cheap and accessible protein source for the farmers. Most farmers also felt that Bambara groundnut was important for keeping their energy levels high throughout the day. This may be due to the high level of carbohydrates (65%) contained in Bambara groundnut (Mazahib et al. 2013). Some farmers also stated that Bambara groundnut helps them with digestion. This comment may be referring to the high level of dietary fibre contained in Bambara groundnut, as described by Yao et al. (2015). Some farmers believed that Bambara groundnut was important in keeping them healthy and strong and some female farmers said that the main reason they grew Bambara groundnut was to provide a healthy snack for their children. A study in Northern Ghana found a similar result as some respondents indicated that the consumption of Bambara groundnut is essential for a child's intelligence and general development (Adzawla et al. 2016a). The statements made by the farmers clearly show that they believe that Bambara groundnut is a healthy and nutritious food source and Bambara groundnuts high nutritional value was considered to be the most important enabler for Bambara groundnut production.

Farmers Enjoyed the Taste of Bambara Groundnut

The taste of Bambara groundnuts was also considered as an enabler of most importance (Scoring 4.8 out of 5) and 5% of farmers considered it to be the most important enabler (See Tables 13 and 14). Bambara groundnut was mostly consumed fresh and was considered a luxury item in the farmers' diet, which aligns with research by Greenhalgh (2000). Fresh Bambara groundnut was thought to taste better than both cowpea and groundnut (See Table 12), which was what most respondents thought in a study conducted in Ghana (Adzawla 2016a).

Bambara Groundnut Was Perceived as an Effective Partner Crop for Maize

The farmers believed that Bambara groundnut was an effective partner crop for maize and improved the sustainability and resilience of maize production. For farmers who intercropped and sole cropped

Bambara groundnut, its nitrogen fixation capability and benefits to soil fertility were considered as an important enabler (3.0) to Bambara groundnut production (See Table 13). For the farmers who intercropped Bambara groundnut, the additional benefits perceived were:

a.) It reduces weeding time

b.) Increase land use efficiency

c.) Reduce evapotranspiration rates from soil

d.) Reduce soil erosion

For farmers who intercropped Bambara groundnut, the additional benefits of intercropping were considered as an important enabler (3.1) and 16% of these farmers believed that it was the most important enabler for Bambara groundnut production.

Planting of Bambara groundnut improved soil fertility

The farmers perceived the nitrogen fixating properties of Bambara groundnut and its ability to improve soil fertility as an important enabler. Low soil fertility is a major constraints to agricultural productivity and is a common phenomenon on marginal soils and in the former homeland regions (Gibson et al. 2005). All farmers in this study believed that they experienced low soil fertility. Soil tests conducted as part of the Letsema programme found that 56% of the farmers interviewed had soil fertilities low enough to become eligible to obtain free NPK fertilizer from the programme. Several studies have discussed the N-fixation benefits of Bambara groundnut and ability to improve soil fertility (Dakora and Keya 1997; Ncube et al. 2007; Kgonyane 2010; Odhiambo 2011; Nyalemegbe and Osakpa 2012). Low soil fertility was therefore a major issue for the farmers which would have likely enhanced the enabler of Bambara groundnuts nitrogen fixation properties. Interestingly, the farmers at Ga Molepo considered the nitrogen fixation capabilities of Bambara groundnut as a stronger enabler to Bambara groundnut production than the other farmers on communal land. The farmers who were using fertilizer and were farming on communal land all obtained their fertilizer for free as part of the Letsema programme, whereas the farmers at Ga Molepo did not qualify for free fertilizer. The fact that the farmers at Ga Molepo had to pay for their fertilizer may have enhanced their perception of the nitrogen fixation properties of Bambara groundnut. Another possible explanation for this may be that the farmers at Ga Molepo owned their land. Secure land tenure has been deemed a necessary pre-condition to adopting long term sustainable farming practices (Whitbread et al. 2010). Because the farmers at Ga Molepo owned their land, they may have had more incentive to improve soil fertility through the planting of legumes such as Bambara groundnut, which is a sustainable method to improve soil fertility (Bloem et al. 2009).

A legume-maize intercropping strategy reduces weeding time, increases land use efficiency and improves soil moisture

The additional enablers perceived by farmers who intercropped Bambara groundnut to the benefits of planting Bambara groundnut to improve soil fertility were:

a.) **Intercropping reduced weeding time and the presence of weeds** – A perceived enabler by farmers who intercropped Bambara groundnut with maize is that it reduced the presence of weeds and thus weeding time. All weeding was performed manually by the farmers and it was reported to be the most labour intensive and time demanding task, which aligns with the finding of Waddington et al. (2007). The dry matter and density of weeds reduces when maize and Bambara groundnut are intercropped compared to when they are both planted as sole crops. This is due to the increased soil shading, caused by the increased canopy cover created by the intercropping combination, which is particularly important at the beginning of seasons when weeds are able to outgrow other crops (Bilalis et al. 2010; Dwivedi et al. 2015). Witchweed (*Striga asiatica*) was identified by the farmers at Makatiane as a major constraint to maize yields and farmers in this village intercropped Bambara groundnut with maize to reduce the occurrence of witchweed. Several studies show that intercropping legumes such as Bambara groundnut reduces the occurrence of witchweed and its negative effects on maize yields. This occurs by Bambara groundnut acting as a trap crop as well as from the effects of increasing canopy cover (Ejeta and Butler 1993; Odhiambo and Ransom 1994; Musambasi et al. 2002; Dereje et al. 2016).

b.) **Intercropping increased land use efficiency** – Farmers who used a maize-Bambara groundnut intercropping strategy believed that this was an effective method of increasing land use efficiency without significantly compromising maize yields. Several studies have shown that a Bambara groundnut-maize intercropping combination required less land to produce the same amount of yields for each crop compared to planting maize and Bambara groundnut as sole crops (Alhassan and Egbe 2013a; Jacob et al. 2014; September 2015; Mkandawire et al. 2016). These studies also show that maize yields are only slightly reduced compared to when planted as a sole stand. Hillocks et al. (2012) stated that Bambara groundnut was a suitable partner crop for more lucrative cash crops because Bambara groundnut is a short crop and does not take up too much space. All farmers considered a lack of available land as a major constraint to farm productivity and therefore maximizing land use efficiency was a high priority for farmers.

c.) **Intercropping reduced evapotranspiration rates from soil** – It was stated by the farmers that intercropping Bambara groundnut with maize improved soil moisture levels. The reason stated was because the Bambara groundnut/maize intercropping combination increased soil shading compared to when maize was planted solely. Intercropping lowers evapotranspiration rates from the soil by increasing soil shading, reducing soil temperature and increasing below-canopy humidity (Ghanbari et al. 2010; Choudhary et al. 2012). This function was particularly important to farmers who did not have access to irrigation, which will be discussed in the barriers chapter.

d.) **Intercropping reduced soil degradation** – The farmers felt that intercropping Bambara groundnut with maize reduced soil erosion. Most communal farming areas in former homeland regions have been overused, resulting in low soil fertility and highly degraded soils, which has consequently resulted in these areas being characterized as a region of very low farming output (Gibson et al. 2005; Odhiambo 2011;). It was apparent that soil degradation was a major issue for many of the farmers in this study, especially since all the farms were located on predominantly sandy soil, which is particularly susceptible to wind erosion and erosion caused by extreme rainfall events (Mrs P Makwela, *pers.comm*. June 2016). Extension officers recommended the planting of legumes such as Bambara groundnut to reduce soil erosion, to the farmers. Intercropping legumes with cereal crops has been shown to reduce soil erosion by an increasing canopy cover and developing subsoil root structures (Dwivedi et al. 2015).

Ease of Storage of Bambara Groundnut and its Resistance to Storage Pests

Bambara groundnut's good storage capabilities and resistant to storage pests were considered by farmers as an important enabler (2.6) (See Table 13). Most farmers felt that Bambara groundnut stored well and post-harvest losses were low when Bambara groundnut was stored correctly (Details of storage methods is discussed in Chapter 4.6). When Bambara groundnut was stored correctly, it was the most resistant to post-harvest pests, relative to groundnut and cowpea (See Table 12). The main method of mitigating weevil damage was to store Bambara groundnut with its shell intact, which significantly reduces the seeds' susceptibility (DAFF 2016). Shelled Bambara groundnut was stored in sealed plastic containers which has a lower infestation by weevil attack compared to jute bags (Ayamdoo et al. 2013). The farmers stated that cowpea was particularly susceptible to weevil attack, with weevil infestations occurring quicker, causing larger yield losses and reductions in seed quality compared to Bambara groundnut. Whilst studies have concluded that cowpea is more susceptible to weevil attack compared to Bambara groundnut (Golab et al. 1998; Cork et al. 2009), most studies also conclude that Bambara groundnut is also highly susceptible to weevil attack during storage, with large yield losses and deterioration of seed quality being reported (Golob et al., 1996; Magagula and Maina 2012; Ayamdoo et al. 2013; Nyamador et al. 2016). In Northern Ghana, Akpalu et al. (2013) found that the largest constraint to Bambara groundnut production experienced by farmers was the crops poor storage capacity. Akpalu et al. (2013) found that farmers were discouraged from producing large quantities of Bambara groundnut in case the supply exceeded the ready markets demands. This was because if Bambara groundnut was stored for extended time periods, weevil infestations would ultimately result in farmers operating at a net financial loss. Farmers in this study either sold or consumed Bambara groundnut quickly whilst it was fresh, leaving only a relatively small amount of Bambara groundnut stored for an extended period, of which most was used for the next planting season. The farmers' perception that Bambara groundnut has a high resistance to storage pests may be due to the small quantity of seeds that was stored for any length of time. If weevil infestations ever became a problem for farmers, more effective storage methods may have to be considered, such as the use of Purdue Improved Crop Storage (PICS) described by Baoua et al. (2014).

Bambara Groundnut's Resistance to Drought

Bambara groundnut's drought resistant characteristics were a minor enabler for Bambara groundnut production (See Table 13). Bambara groundnut was perceived by the farmers to be the most drought resistant legume cultivated (Table 12). According to the farmers, the 2015/2016 Bambara groundnut crop experienced the lowest yield losses compared to all other crops grown on both irrigated and non-irrigated land, with the most significant difference occurring at sites with no irrigation. The results support several studies that have shown that Bambara groundnut has high drought resistance (Mwale et al. 2007; Chai et al. 2016; Shareef et al. 2013). The results show that the crop's high drought resistance was considered an inferior enabler to the value it provides in supporting the farmers food and economic security. This supports Mayes et al.'s (2012) argument that there is simply no point in cultivating a crop that has the ability to withstand environmental stressors, if the crop does not provide anything of food or economic value. Due to the likely effects of climate change in the region, the high drought resistance of Bambara groundnut may become a more important enabler for the crops production in the future.

Cultural Beliefs on Bambara Groundnut Production

A minor enabler for Bambara groundnut production by farmers was that the crop was cultivated by their ancestors and they wanted to preserve this tradition. Bambara groundnut is a traditional crop grown by small scale farmers in the Northern and Eastern regions of South Africa and it's believed to have been brought to the country by migrating peoples from Central Africa by either the Bolebedu of Letaba or the Venda (Swanevelder 1998). Within South Africa, folklore, traditions and cultural beliefs surround Bambara groundnut production, which influences farmers' utilization of the crop; however it is currently unknown as to the extent that some of these traditions persist (Swanevelder 1997; Matthews2013). when interviewed (in June 2008), Mrs P Makwela highlighted that. Makwela (2016) highlighted that since their initial encounters with farmers the traditional practices of Bambara groundnut production were not in accordance with best known agricultural practices. When interviewed (June 2016) Cate explained that local cultural beliefs used to forbid the early planting of Bambara groundnut. Matthews (2013) described a similar tradition still present in Mpumalanga and this results in low Bambara groundnut yields. In more remote rural regions Cate also believed that there are still strong cultural traditions that persist, which would affect Bambara groundnut yields, however no other specific traditions were mentioned. The results appear to support Pungulani (2012): that Agricultural Extension Officers play a vital role in educating farmers so that they can maximize the benefits of cultivating Bambara groundnut.

Use of Bambara groundnut crop for livestock feed

Farmers regarded the use of Bambara groundnut for use as animal feed as an enabler of minor importance. Only the leaves of the Bambara groundnut plant were used for animal feed, which is a common practice for farmers in South Africa (DAFF 2011). None of the farmers in this study used the seeds for animal feed as they valued them more as food for human consumption.

5.3.2: Common Barriers

The barriers described by the farmers can be separated into barriers that are specific to Bambara groundnut, and generic barriers to agriculture. Common barriers that were specific to Bambara groundnut were a) The low yielding characteristics of the crop; b) Bambara groundnut is labour intensive to cultivate; and c) The crop is susceptible to waterlogging. Generic common barriers include a) Insufficient farmland available; b) Lack of irrigation; c) Land management constraints; and d) Availability of credit.

Bambara groundnut is low yielding compared to other crops

All farmers agreed that Bambara groundnut was the lowest yielding legume planted (See Table 12). Overall, the low yielding characteristic of Bambara groundnut was considered a very important barrier to Bambara groundnut production (Scoring of 4.4 out of 5, as shown in Table 15). It was also the second most frequently stated main constraint to Bambara groundnut production (See Tables 16). In Northern Ghana, it was also found that farmers perceived Bambara groundnut's low yielding capability as a major barrier to Bambara groundnut production (Akpalu et al. 2013; Adzawla et al. 2016b). For the farmers who used a legume-maize intercropping strategy, the low yielding characteristics of Bambara groundnut was the primary reason for Bambara groundnut being allocated the least amount of land out of all the main crops grown. The farmers who were primarily cultivating Bambara groundnut for household use prioritized the higher yielding legumes, cowpea and groundnut. A study in northern Ghana found that the main reason why 25.9% of interviewed farmers had not adopted Bambara groundnut production was because they instead preferred to cultivate legumes such as cowpea and groundnut that were higher yielding (Adzawla et al. 2016b). Interestingly, the farmers who intercropped Bambara groundnut perceived the crop's low yielding characteristics as a larger barrier to its production compared to the farmers at Ga Molepo who sole-cropped Bambara groundnut (See Tables 15 and 16). As discussed earlier, Bambara groundnut yields are inhibited when intercropped with maize compared to when cultivated as a sole crop. Therefore, the different planting methods used by farmers most likely influenced the farmers perception of Bambara groundnuts yielding performance.

Lack of available farmland

A barrier of most importance to all farmers was a lack of available farmland (scoring of 5). All farmers who intercropped Bambara groundnut with maize farmed on communal land and the farmers had trouble acquiring extra farmland for free that was suitable for crop production. The farmers could have purchased extra land for farming purposes, however most had insufficient funds to do this. A lack of available land in Limpopo has been found to be a significant factor in determining whether a farmer can

participate in the market (Hllongwane et al. 2014). Land Reform envisaged a redistribution of 30 percent of land to Historically Disadvantaged Individuals (HDI) to redress the unequal distribution of land, in which only 13 percent was allocated to the former Bantustans (Mapedza et al. 2015). Whilst it was likely that many of the farmers would have planted extra Bambara groundnut, they would have only planted it in the current proportions planted. It is therefore most probable that the farmers from Peskebult, Ga Raphere, Makatiane and Ga Mogano would have only planted a small amount of extra Bambara groundnut. The farmers at Ga Molepo however would have devoted a larger amount of the extra land to Bambara groundnut production.

Lack of irrigation

For farmers without access to irrigation, this factor was perceived as a barrier of most importance, with 21% of farmers (6 farmers without irrigation) considering a lack of irrigation to be the most important barrier to Bambara groundnut production. In this study, it was found that most farmers interviewed did not have access to irrigation, which is the case for most small scale farmers in South Africa (Perret 2001). Irrigation farming has been widely seen as a method to significantly enhance the productivity of small scale farmers and reduce poverty (Norton 2004; Meliko et al. 2010). Irrigation has been highlighted as a method of reducing farmers' vulnerability to droughts (Shiferaw et al. 2013). From the results it appeared as though the drought has no effect on the available water for farmers at Peskebult nor farmers at Ga Molepo. It was clear from the results that whilst the drought during the 2015/2016 cropping season had no effect on the Bambara groundnut at sites with access to irrigation, the drought significantly affected the Bambara groundnut yields at sites without irrigation. Despite Bambara groundnut having a high drought resistance relative to other crops, mild water stress results in lower yields of Bambara groundnut and severe water stress will cause significant yield losses of Bambara groundnut (Mwale et al. 2007; Shareef et al. 2013; Chai et al. 2016). During drought periods, the use of irrigation, given sufficient available water, would significantly reduce, if not completely prevent, yield losses that occur due to the drought.

The mean annual precipitation in areas where farmers had no access to irrigation is 500-600mm a year and the annual precipitation for optimal yields of Bambara groundnut is 900-1200mm (Brink and Belay 2006). As part of the Bamlink project an evaluation of yield performance of 9 Bambara groundnut landraces grown in Swaziland, Namibia and Botswana was conducted and they concluded that rainfall distribution was the main factor influencing yield performance (Azam Ali et al. 2004). In that project the yields recorded in Luve, Swaziland with a recorded rainfall of 633mm, which was similar to the annual rainfall at sites in this study, where, with no irrigation, average yields of 649kg/ha were obtained. All landraces performed worse compared to the field site at Malkerns in Swaziland, which experienced an average rainfall of 728 mm and average yields of 1582kg/ha. The findings from the BAMLINK project show strong evidence that supplementary irrigation would also likely cause significant yield improvements for Bambara groundnut during normal climatic years as well as during drought periods.

Land Management Constraints to Bambara Groundnut Production – Soil Not Ploughed Deep Enough

It was claimed by the farmers at Ga Ramphere that a major barrier to Bambara groundnut yields was due the soil not being ploughed deep enough. At Ga Ramphere the farmers felt that the hired tractor labour was not ploughing deep enough, which was considered as a barrier of most importance for these farmers. The general guidelines for Bambara groundnut production is that the crop yields are best on deeply ploughed soils prepared with a fine seed bed (Swanevelder 1997; Brink and Belay 2006; DAFF 2016). Usually 20-30cm plough depth is sufficiently deep enough in most soil types for optimum Bambara groundnut yields (Dr C Madakadze 2016, *pers.comm*, June). Dr C Madakadze (when interviewed in September 2016) however mentioned that it is likely that ploughing service providers sometimes cut corners in order to save time and fuel and the 20-30cm ploughing depth was not achieved, particularly when soils are dry. If the soil was not ploughed deeply enough, then it is likely that this would likely have a negative effect on Bambara groundnut yields. Therefore those with good irrigation would more likely achieve optimum depths for Bambara groundnut production, since these farmers can irrigate the soil prior to ploughing. In dry seasons, it is likely that farmers without irrigation will not achieve optimum depths for Bambara groundnut production if the ploughing service providers are attempting to cut corners.

Lack of Credit

A lack of credit was considered as only a minor constraint to Bambara groundnut production, with a mean weighting score of 2.2 (See Table 15) and only 5% of farmers thought that a lack of credit was the main barrier to Bambara groundnut production. A lack of credit was regarded as a major barrier to many of the farmers residing in Perskebult because they could not afford to purchase fertilizer for Bambara groundnut, which they thought would improve yields; another small group of farmers could not afford to purchase sufficient fencing for crops, permitting cows to trample on Bambara groundnut. Whilst a lack of fencing is a common constraint to agricultural communities farming in the former homeland areas (Baiphethi and Jacobs 2009), it is uncommon for farmers to believe that a lack of fertilizer is a constraint to Bambara groundnut production. It is not uncommon for farmers to grow Bambara groundnut without any form of fertilizer and often it is reported that farmers believe that Bambara groundnut prefers depleted soils (National Research Council 1979; Mkandawire 2007; Alhassan and Egbe 2013; Akpalu et al. 2013). Whilst the application of nitrogen fertilizer alone may inhibit the nitrogen fixation properties of Bambara groundnut (Ramolemana 1999), the use of fertilizers (such as Fertilizer 2:3:2 (N:P:K) and fertilizer containing phosphorous and potassium only) have shown in field studies to improve yields of Bambara groundnut (Toungos et al. 2010; Kakusko and Dakato 2015). Most farmers however did not see a lack of credit as a significant barrier to Bambara groundnut production.

Bambara Groundnut Perceived By Some Farmers as a Labour Intensive Crop

Some farmers perceived Bambara groundnut as a labour intensive crop to cultivate and four farmers (9%) thought that this factor was the largest barrier to Bambara groundnut production. Overall however, labour constraints were only considered as a minor barrier to Bambara groundnut production (mean weighting score of 2.1). Alhassan and Egbe (2013) found in their case study in Nigeria that labour constraints was the largest constraint to production. Many of the farmers in this study were old (>65)

and the fact that Bambara groundnut is a low lying crop, which has to be uprooted to attain the Bambara groundnut would have likely have been a difficult task for many of the farmers.

Bambara Groundnut susceptible to water logging

Bambara groundnut's susceptibility to waterlogging was considered as a minor constraint to crop production (mean value of 1.8). Farmers reported that heavy rains can cause water logging of Bambara groundnut and cause complete crop failure. Bambara groundnut is known to be susceptible to waterlogging and the short term flooding reduces the germination rate of Bambara groundnut seeds by 60-80% (Brink and Belay 2006; Sesay 2009). To mitigate against the risk of waterlogging, farmers planted Bambara groundnut on ridges, but often this strategy did not prevent the crop from waterlogging. Some farmers mentioned that an advantage of cowpea was that it was less susceptible to waterlogging compared to Bambara groundnut. Overall, due to low frequency of flooding events, farmers considered the susceptibility of Bambara groundnut to water logging as only a minor issue.

5.4: Bambara Groundnut Attributes that Had Conflicting Views among Farmers

The major conflicting views around Bambara groundnut production and use, was the crop's resistance to pests whilst in the field, and its overall effectiveness as a cash crop. Due to the significant conflict in opinion, these two attributes of the crop are discussed on a village level of analysis, as there were major differences of opinion between different villages.

Bambara Groundnuts Pest resistance whilst in the Field

A major difference in the farmers' views on Bambara groundnut was the crop's resistance to pests whilst in the field. It was clear that farmers believed that Bambara groundnut was more resistant to field pests than groundnut and cowpea (See Table 12). Cowpea was considered to be the most susceptible to yield losses whilst in the field primarily due to aphid attacks, supporting Asiwe (2009). Groundnut was considered to be more susceptible to termite attack. Termite infestations have been highlighted as a major pest to maize and legumes in the Limpopo province, particularly to farmers without access to irrigation (Mphosi et al. 2009; Randela 2010). The results support Tanimu and Aliyu (1997) observation that Bambara groundnut appears to have a higher resistant to insect pests compared to groundnut and cowpea.

Whilst Bambara groundnut was considered to be more pest resistant compared to cowpea and groundnut, there was a large discrepancy on the extent to which farmers consider that it is affected by field pests and how this influences production of the crop. Half of the farmers believed that pests affecting Bambara groundnut were not a significant problem, which several studies have concluded (Heller et al. 1997; Mkandawire 2007; Bamshaiye et al. 2011; Hillocks et al. 2012; Akpula 2013). The

farmers who felt that Bambara groundnut was susceptible to pest attack was mainly because of birds, eating the seeds during the planting and harvesting of the crop. An agricultural extension officer present during the discussions and an expert in Bambara groundnut production in South Africa considered that it was likely that it was guinea fowl that was eating the seed (Mrs M Cate June 2016, Mr C Madakadze June 2016, *pers.comm*). The farmers who experienced this problem had no method of combating it and believed that this was a very important barrier to Bambara groundnut production. As discussed earlier, some of the farmers used to acquire the help of children to scare away the birds, however this strategy was no longer possible because the children had to go to school. It appears birds can be a significant threat to Bambara groundnut during the planting and harvesting of the crop, however the impact of birds is subject to location.

Bambara Groundnuts effectiveness as a cash crop

In this study it was found that the farmers who produced Bambara groundnut for primarily household purposes (the farmers from Perskebult, Ga Ramphere, Makatiane and Ga Mogano) believed that all legumes, including Bambara groundnut were not effective cash crops. The main reason why these farmers considered Bambara groundnut to not be an effective cash crop was because maize was significantly more profitable for the farmers which aligns with Waddington et al. (2007). These farmers were able to obtain a higher price per kilogram for Bambara groundnut compared to maize and most of these farmers felt that local demand was higher than supply. Ultimately however the low yielding characteristics of Bambara groundnut made maize production a much more attractive option. The low yielding characteristics of Bambara groundnut was also an important barrier for the farmers at Ga Molepo, however these farmers still believed that Bambara groundnut was an effective cash crop. The fact that the farmers at Ga Molepo (who irrigated their Bambara groundnut and planted it as a sole crop) had recently bought extra land for the sole use of Bambara groundnut production, which would double their scale of production, highlights that these farmers believed that Bambara groundnut was a profitable crop. The disparity in views as to the effectiveness of Bambara groundnut as a cash crop between the farmers at Ga Molepo and the other farmers is likely due to:

a.) The differences in maize yields obtained and how this effects the marketing of maize

b.) The differences in the performance of Bambara groundnut when intercropped with maize compared to when sole cropped

c.) The difference in scale of Bambara groundnut production.

d.) The availability of irrigation

For all farmers in this study, maize was the primary staple and cash crop, which is common for small scale farmers in Limpopo (Hlongwane et al. 2014; Moriri et al. 2015). The farmers at Ga Molepo were able to obtain significantly higher yields of maize compared to the other farmers, due to drip irrigation (Meliko et al. 2010). Due to the high maize yields obtained by the farmers at Ga Molepo, they were the only farmers who had to regularly sell to local maize millers. According to the farmers, the price obtained at local markets was 50% more for maize compared to when sold to local millers, which was a

similar finding to (Biénabe and Vermeulen 2011). Therefore, for the farmers at Ga Molepo, the benefits of increasing maize production were lower compared to the other farmers, which likely enhanced the attractiveness of producing other crops (i.e. Bambara groundnut) to sell through local markets. As discussed earlier, greater yields are obtained from planting Bambara groundnut as a sole crop compared to intercropping it with maize, as several studies have shown. (Friesen and Palmer 2004; Jacob et al. 2014; September 2015; Mkandawire et al. 2016). The farmers at Ga Molepo were the only farmers to sole crop Bambara groundnut, allowing these farmers to obtain larger yields of Bambara groundnut and hence improve the crop's profitability.

Another factor discussed previously was that the farmers at Ga Molepo produced Bambara groundnut on a significantly larger scale compared to the other farmers. As well as this, the farmers at Ga Molepo were able to produce consistently higher yields of Bambara groundnut because of their access to drip irrigation. Both of these factors made them a primary source of Bambara groundnut in the region and enabled them to sell a greater volume of Bambara groundnut at up to a 40% higher price compared to the other farmers. The higher market price acquired by the farmers at Ga Molepo would have positively influenced their perception of Bambara groundnut as a cash crop. The comparatively larger scale of Bambara groundnut production performed by the farmers at Ga Molepo would have likely improved the efficiency of Bambara groundnut production according to Adzawla et al. (2015), and may have also positively influenced their perception of Bambara groundnut as an effective cash crop. Overall the results indicate that Bambara groundnut can be a profitable crop for small scale farmers in South Africa, similar to what has been found in studies conducted in Kenya and Ghana (Wasula et al. 2014; Adzawla 2016).

Chapter 6: Summary of Findings and the Potential for Future Benefits for the Farmers

The primary enablers perceived by the farmers for Bambara groundnut production were associated with the benefits of producing the crop for household consumption. In particular Bambara groundnut was considered a healthy and nutritious food source and farmers enjoyed the taste of Bambara groundnut. Secondary enablers to Bambara groundnut were associated with the nitrogen fixation properties of Bambara groundnut plant and its associated benefits to being incorporated into a maize based farming system. The minor enablers for Bambara groundnut production were associated with the crops drought resistance, cultural traditions of cultivating the crop and its use as livestock feed. The main perceived barriers to Bambara groundnut production were associated with the low yielding characteristics of Bambara groundnut, the lack of available farmland and a lack of irrigation. Other barriers that were overall of minor importance were the poor management practices, low soil fertility, and the crops susceptibility to water logging. An overview of the enablers and barriers perceived by the farmers are presented in Table 17.

The primary purpose for most farmers producing Bambara groundnut was to support household nutrition and to support maize production. It is unlikely that many of the enablers highlighted by the farmers would have been perceived so highly if it was not due to the educational support provided by

the Agricultural Extension Officers. Hence it appeared as though the Agricultural Extension Officers positively influenced farmer's perceptions of Bambara groundnut and encouraged them to utilize the crop. It was however found that the farmers at Ga Molepo were practicing Bambara groundnut production methods (i.e. presoaking the Bambara groundnut seeds prior to planting) which the farmers learnt through indigenous knowledge systems rather than from the Agricultural Extension Officers. The Agricultural Extension Officers were not aware of some of these practices; furthermore, these practices are not reported in South Africa's Bambara groundnut production manual (DAFF 2016). This finding highlights the importance of indigenous knowledge systems and that lessons can be learnt from farmers to improve agronomic practices, supporting Dlamini and Kaya (2016).

It was found that some farmers would have preferred to have eaten more fresh Bambara groundnut, however their consumption was constrained by the low yields they obtained. It is therefore likely that improvements in Bambara groundnut yields would result in some farming household increasing their consumption of fresh Bambara groundnut. Due to the high nutritional value of Bambara groundnut, increased consumption of Bambara groundnut would have positive effects on a farming household's food security. It was also perceived by farmers that in most villages, demand was higher than supply and due to the high market value of Bambara groundnut, there appeared to be economic opportunities for farmers to achieve an economic benefit, if they could obtain higher yields. The farmers at Ga Molepo, who produced Bambara groundnut primarily for commercial reasons show that there are economic opportunities for Bambara groundnut, and this scale of Bambara groundnut production in South Africa is higher than what has been described in the previous literature (DAFF 2016). The key factors which set apart the farmers at Ga Molepo to the other farmers are their access to effective irrigation, as well as there larger farms, which allow them to devote more land to both maize and Bambara groundnut. The fact that they are a younger generation compared to the other village farmers, with more resources, are arguably more motivated and focused on crop production, management, sustainability and investment. Crucially their yields and quantities of production of Bambara groundnut are of a level which together with an established local market enables them to produce a regular annual income albeit seasonal in relation to availability of fresh produce. Furthermore the fact that they are buying more land for the purpose of doubling the size of their Bambara groundnut production is an endorsement of Bambara groundnut as a cash crop. Overall the study's findings align with Matthews (2010) statement that there is great potential to increase Bambara groundnut production and utilization in South Africa.

Arguably one of the most important findings of this study was that overall the farmers were positive about Bambara groundnut production and were motivated to keep on producing the crop. The findings suggest that the farmers in this study would be supportive to developments in Bambara groundnut production and would benefit from improved landraces with higher yields. From the demographics of farmers interviewed in this study, it can be reasonable to assume that mostly small scale female farmers would benefit from developments in Bambara groundnut production. Advancements in Bambara groundnut production therefore have the potential to target some of South Africa's most impoverished and disempowered sections of society. Several studies have found that in some African countries where crop improvements have led to increased economic opportunities, males have become more involved in the crops production and this has resulted in lower female participation in crops production (Carney and Watts 1990, 1991; Kumar 1994; Dolan 2001; Fischer and Qaim 2012). There is therefore a danger that if higher yielding varieties of Bambara groundnut are developed then this may reduce female participation

in growing the crop. A strategy must therefore be in place in order to maintain women's participation in Bambara groundnut production.

It must be emphasized that whilst Bambara groundnut has great potential to improve farmer's food and economic security, as highlighted by Waddington (2007) maize is by far the most profitable cash crop. However because of the potential for grain legumes to improve soil fertility and long term productivity of maize, it is vital that farmers are encouraged to plant legumes, but maize should be the primary focus for the small scale farmers. Currently the farmers are growing Bambara groundnut as a mixture of landraces in order to maximize yield stability and mitigate the impact environmental stressors, as described by Massawe et al. (2005). Selection of seed is necessary in order to develop higher yielding varieties of Bambara groundnut (Massawe et al 2005; Aliyu et al. 2015; Aliyu et al. 2016). Whilst traditional plant breeding methods would likely take many years to develop high yielding varieties of Bambara groundnut, this is no longer the case due to new biotech screening methods (Aliyu et al. 2015; Aliyu et al. 2016). It is therefore unlikely that significant advancements in Bambara groundnut production will be achieved without support from the Department of Agriculture, Fisheries and Forestry's, research institutions and relevant NGO's.

Table 17: Overview of Farmers Enablers and Barriers Perceived by Farmers for Bambara Groundnut Production

Level of Importance	Enablers	Barriers
Most Important	Healthy and Nutritious for source	Lack of improved varieties
	Good Taste	Lack of Available Farmland
Very Important		Lack of Irrigation
Important	Nitrogen Fixator	
	Effective Intercrop	
	Stores well/High storage pest resistance	
Minor Importance	Traditional Crop	Poor Soil fertility
	High Drought Resistance	Lack of Credit
	Animal Feed	
	Cash Crop	Pest Resistance in the field
	Pest Resistance in the field	Lack of local market

Chapter 7: Recommendations to support Farmers with Bambara Groundnut Production and Recommendations for Future Research to Support Bambara Groundnut Producers

7.1: Recommendations to Support Farmers with Bambara Groundnut Production

Increase the number of agricultural extension officers in South Africa – Many of the enablers perceived by the farmers (e.g the nitrogen fixation properties of Bambara groundnut and the nutritional qualities of Bambara groundnut) were recognised due to the support provided by agricultural extension officers. If the agricultural extension officers had not been there, then the full value of planting Bambara groundnut would not have been appreciated and it is likely that many of the farmers interviewed would be planting maize only. It is therefore evident that the consultation support provided by the agricultural extension officers positively influenced the farmers perceptions of Bambara groundnut and encouraged them to adopt more sustainable and nutrition-sensitive agricultural systems. The findings therefore supports Davis and Terblanché (2016) argument that agricultural extension services are a vital knowledge sharing institution and are critical to supporting social, economic and environmental development in rural areas. It was found by Akpalu (2013) that a large number of small scale farmers in Limpopo did not receive support from agricultural extension officers due to the lack of agricultural extension officers. Increasing the number of agricultural extension officers would enable more farmers to receive support from agricultural extension officers, which would likely enable them to increase farm productivity.

Enhancing farmers awareness of best known agronomic practices for Bambara groundnut production

Most of the agronomic practices for Bambara groundnut production by the farmers were considered to be best known practices by the agricultural extension officers. Certain good agronomic practices however were only conducted by farmers in a certain village, who learnt the practices through indigenous knowledge systems rather than the agricultural extension officers. For example, the pre-soaking of Bambara groundnut seeds prior to planting, which has been found to improve the germination of Bambara groundnut seeds (Berchie et al 2010b). The pre-soaking of seeds was not a practice recommended by the agricultural extension officers, nor is it recommended in South Africa's Department of Agriculture, Forestry and Fisheries' Bambara Groundnut Production Manual (DAFF 2016). It is therefore likely that many other Bambara groundnut producers are not presoaking their seeds prior to planting and are not being advised by agricultural extension officers. Due to the limitations of the study, it is highly likely that agricultural extension officers could advise other low cost and effective methods to improve farmer's productivity of Bambara groundnut.

Support for farmers to selecting high yielding accessions of Bambara groundnut - It was found in this study that the farmers were using locally derived unimproved landraces. Many of the farmers would have been able to sell more Bambara groundnut and some would have likely eaten more Bambara

groundnut if they could have obtained higher yields. Therefore most farmers would likely benefit from the development of improved varieties of Bambara groundnut, which supports the argument made by several studies (Azam Ali et al. 2004; Mayes 2008; Aliyu et al. 2015; Aliyu et al. 2016).

7.2: Recommendations for Future Research to Support Small Scale Farmers in Bambara Groundnut Production

Research into developing improved Bambara groundnut varieties – If research could develop high yielding Bambara groundnut landraces that were socially acceptable to the farmers, then farmers could utilize these improved varieties to enhance their food and economic security. New biotech screening methods could be used to significantly reduce the time needed to develop high yielding Bambara groundnut varieties (Aliyu et al. 2015; Aliyu et al. 2016). Developments into improving Bambara groundnut yields have already been achieved at the University of Nottingham in both the UK and Malaysia campus (Aliyu et al. 2016; Musa et al. 2016). It's argued by Wale and Yalew (2007) that when investigating new high potential crop varieties, farmers' preferences in varieties should be integrated into research at an early stage in order to enhance adoption rates. In Malawi, researchers worked alongside farmers in order to identify high yielding bambara groundnut landraces that were also considered to be socially acceptable (Pungulani et al. 2012). South African research institutes could support farmers by conducting similar research into developing improved Bambara groundnut varieties.

Enquiry into developing marketing strategy for Bambara groundnut – Currently all the farmers sell their Bambara groundnut through local informal markets. Whilst most farmers involved in this study felt that this marketing strategy was currently adequate, if farmers start to obtain significantly higher yields, then local supply would outstrip. Research into developing formal markets for Bambara groundnut could create new economic opportunities for farmers and allow them to sell larger quantities of Bambara groundnut.

Investigation into improved storage methods – Whilst the farmers did not believe that storage was a significant barrier to Bambara groundnut, this may have been because the farmers were only storing a small amount of Bambara groundnut for long periods of time. A storage investigation could identify methods to reduce post-harvest losses, which may potentially become a significant issue for the farmers if they are able to acquire higher Bambara groundnut yields.

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Appendix A: Ethics Protocol for Research Work in the Villages visited in the Capricorn District of Limpopo Province

Project Title: Farmers perceptions of the barriers and enablers of Bambara groundnut (*Vigna subterranean*) production and its effect on food and economic security in South Africa: A case study in Limpopo

Invitation to participate, and benefits: You are invited to participate in a research study conducted with Bambara groundnut farmers. The study aim is to evaluate whether farmers may be able to improve their food and economic security through increased utilisation of Bambara groundnuts. I believe that your experience would be a valuable source of information, and hope that by participating you may gain useful knowledge in optimising Bambara groundnut yields to help improve food and economic security.

Procedures: During this study, you will be asked to complete a survey about your experiences with producing Bambara groundnuts and what you feel are the benefits and drawbacks of farming Bambara groundnut.

Risks: There are no potentially harmful risks related to your participation in this study.

Disclaimer/Withdrawal: Your participation is completely voluntary; you may refuse to participate, and you may withdraw at any time without having to state a reason and without any prejudice or penalty against you. Should you choose to withdraw, the researcher commits not to use any of the information you have provided without your signed consent. Note that the researcher may also withdraw you from the study at any time.

Confidentiality: All information collected in this study will be kept private in that you will not be identified by name or by affiliation to an institution. Confidentiality and anonymity will be maintained as pseudonyms will be used.

What signing this form means:

By signing this consent form, you agree to participate in this research study. The aim, procedures to be used, as well as the potential risks and benefits of your participation have been explained verbally to you in detail, using this form. Refusal to participate in or withdrawal from this study at any time will have no effect on you in any way. You are free to contact me, to ask questions or request further information, at any time during this research.

I agree to participate in this research (tick one box)

☐ Yes ☐ No _____ (Initials)

_____	_____	_____
Name of Participant	Signature of Participant	Date

_____	_____	_____
Name of Researcher	Signature of Researcher	Date

Appendix B: Questionnaire used During Interviews with the Farmers and During Discussion Groups

Farmers Perceptions of The Barriers and Enablers to Bambara Groundnut Survey
Identification of Household
Interview Number ……. Interview Location …….. Date of Interview ……..

Section 1 – Farmers Demographics, Overview of Farming Systems and Purpose of Farming				
Section 1B : Household Composition				
Household size				
1b Sex (✓)	Male		Female	
1c Age (✓)	<35	36-45	46-64	65+
sources of income in household Selling crops, labour, remittances	Source			
	Source			
	Source			
	Source			

Section 1D – Household farming overview		
What is the total area of land that you cultivate?		Ha
What crops do you cultivate and what area of land is provided to each crop	Crop	Ha
	Crop	Ha

Identify whether cash or subsistence crops	Crop	Ha
	Crop	Ha
	Crop	Ha
	Other Crops	
Extension Visits		
How many times a year does an agriculture official visit your community per year		

Section 1E - Purpose of Farming and Amount of Food Purchased				
Tick the most appropriate box (✓)	Farmer produces all food to eat	Farmer produces most food to eat but sells some	Farmer produces most food to sell	
a. Do you grow enough food to eat?			Yes	No
Measure as a percentage of the total amount of food required by the household Use the following scale: b. No Food for household consumption c. 0%-25% of household consumption d. 25%-50% of household consumption e. 50%-75% of household consumption f. 75%-100% of household consumption				
How much food do you buy	ZAR:			

Section 2 – Bambara Groundnut Production		
Section 2a - Identification of Bambara groundnut farmer		
Are you the member of the household responsible for Bambara groundnut production (If not then which member of the family is responsible for Bambara groundnut production)	Yes	No Member if household -
Section 2b - Planting and harvesting times of Bambara groundnut		
Planting Bambara Groundnut		
When do you plant Bambara groundnut? *(Specify months)*		
Harvesting Bambara Groundnut		
When do you harvest your Bambara groundnuts *Specify months*		
Do you plant Bambara groundnut as a sole crop or as an intercrop in a piece of land?	a. As a sole crop	
	b. As an intercrop	
What do you intercrop Bambara groundnut with *(Skip this question if answer to previous question is 'As a sole crop) Specify crop in adjacent box*		
Do you apply fertilizer to Bambara groundnut *(If yes then specify fertilizer used)*	Yes	No
Do you apply pesticides to Bambara groundnut (If yes then specify pesticide used)	Yes	No
Why do you/do not apply fertilizer/pesticide		

Section 2c - Bambara Groundnut Production	
How many years has your family been involved in growing Bambara groundnut?	Years
Over the last 10 years, has the household done the following to Bambara groundnut	a. Increased levels of production
	b. Decreased levels of Bambara groundnut production

	c. Maintained the same levels of Bambara groundnut production
What are the reasons why you have increased/ decreased/ maintained levels of Bambara groundnut production	
How many hectares of Bambara groundnut do you grow per year?	ha

How many kilograms of Bambara groundnuts do you normally produce per year? *Note – During a year where the weather is more ''normal''* Do you find that the yields vary each year or are stable? How do the yields compare to other crops you produce?	Kg
How many kilograms of Bambara groundnuts did you produce this year? *Note – During the drought year*	Kg
Do you find that during unfavourable climates for agriculture, does Bambara groundnut still produce reasonable yields?	

What are the main reasons why you do not produce more Bambara groundnuts *If respondent does not reply then provide some suggestions such as better yielding varieties, too labour intensive*	
In the future will you continue to grow Bambara groundnut	

Section 2d - Pests, diseases and yield losses of Bambara groundnut	
What diseases effect Bambara groundnut. What is the level of impact do the diseases cause to Bambara groundnut yields *Rate the level of impact from low, medium or high. Write additional notes if necessary*	
What pests effect Bambara groundnut whilst in the field *Rate the level of impact from low, medium or high. Write additional notes if necessary*	
What pests effect Bambara groundnut during storage	

Rate the level of impact from low, medium or high. Write additional notes if necessary	
Are more Bambara groundnut yields lost whilst in the field or during storage?	
Compared to other crops grown (in particular other legumes grown), how much is Bambara groundnut impacted by pests and diseases.	
What strategies are used to reduce yield losses (either whilst Bambara groundnut it still growing or during storage.	
Section 2E - Storage Method of Bambara Groundnut	
How do you store your Bambara groundnuts	
How long do Bambara groundnut last whilst in storage?	Months
Additional Notes	

Section 2F - Reason for growing Bambara groundnuts		(✓)
	a. For subsistence use only	

Out of the following choices, what best describes your reason/s for growing Bambara groundnut *(READ the choices and tick the most appropriate box)*	b. For subsistence use and as a cash crop	
	c. Mostly to Sell	
	d. For social reasons (i.e. funerals or having inherited the tradition of growing Bambara groundnut from families	
	e. Other (Specify)	

Section 2G - Consumption of Bambara groundnut	
How often do you consume Bambara groundnut throughout the year? Use the following code – (1) not at all, (2) Less than once a month (3) Once every 2-4 weeks (4) Once every 2 weeks (5) Once a week, (6) 2-4 times a week (7) 4-6 times a week (8) everyday	
Month	Score
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	
How do you normally eat Bambara groundnut? *List what foods Bambara groundnut Is normally used for (e.g. flour, Okpa etc.)* How do you normally eat Bambara groundnut? *List what foods Bambara groundnut Is normally used for (e.g. flour, Okpa etc.)*	

Section 2H - Cultural and Social Spheres of Bambara Groundnut production	
Do you use Bambara groundnut in any ceremonies/traditional events? Investigate the frequency in which it is used as well as what the event is.	

Are there any traditions surrounding Bambara groundnut Note - Try to understand if there are any cultural beliefs, folklore or superstitions related to Bambara groundnut	

Section 2I - Trading of Bambara Groundnut		
What proportion of Bambara groundnuts do you sell? How much does this vary each year?		
What is the high, low and average price of selling Bambara groundnuts *How does this compare to the price of other crops sold*	High price	R
	Low price	R
	Average price	R
How do you normally sell Bambara groundnuts *DON'T READ* *Options may be:* *1.)* Household sells directly to consumers *2.)* Household sells to informal Bambara groundnut traders *3.)* Other - specify		
When do you sell Bambara groundnut *(Specify Months)*		
How does the demand for Bambara groundnut compare to the supply *Scoring system* *1. Supply significantly exceeds demand* *2. Supply exceed demand* *3. Supply is balanced with demand* *4. Demand exceeds supply* 5. *Demand significantly exceeds supply*		
If Farmer does not sell them then why not?		

Would it be preferable to sell your Bambara groundnut or consume them?	
Do you think that if you could/were able to produce more Bambara groundnut it would improve your food security and economic prospects?	

Section 3 Farmers Perceptions to Bambara groundnut Production	
Section 3A Farmers Perceived Enablers to Bambara Groundnut Production	
What are the reasons why you grow Bambara groundnut? *List what farmers say are the main reasons for growing Bambara groundnut. Ask farmers to elaborate on what is said.* *If researcher feels that discussion is not flowing then ask questions that may relate to enablers*	
Out of the reasons discussed for growing Bambara groundnut, what is the main reason for growing Bambara groundnut? Explain why the main reason? Discuss the reason in detail.	
Section 3b – Ranked Enablers to Bambara groundnut production	

Ask the farmer rank the following reasons for growing Bambara groundnut Note: Include additional enablers mentioned by farmers in section 3A Scoring System: (1) Not an enabler, (2) A minor enabler, (3) An Important enabler, (4) A very important enabler, (5) An enabler of most importance		
Reason	Score	Additional Notes
Traditional Crop		
Good Taste		
Healthy and Nutritious Food Source		
Pest Resistance (in field)		
Pest resistance (During Storage)		

High Drought Resistance		
Nitrogen fixator/improves soil fertility		
Cash Crop		
High Market Value		
Nitrogen Fixator/Improves soil fertility		
Animal Feed		
Effective Intercrop		

Medicinal Purposes		
Additional reason 1		
Additional reason 2		
Additional reason 3		
Section 3C Farmers Perceived Barriers to Bambara Groundnut Production		
What are the problems with growing Bambara groundnut? *List what farmers say are the problems with growing Bambara groundnut. Ask farmers to elaborate on what is said.* *If researcher feels that discussion is not flowing then ask questions that may relate to the barriers*		
Out of the problems discussed with growing Bambara groundnut, what is the main problem with growing Bambara groundnut? Explain why the main problem? Discuss the issue in detail.		

Ask the farmer rank the following reasons for growing Bambara groundnut Note: Include additional enablers mentioned by farmers in section 3A Scoring System: (1) Not a barrier, (2) A minor barrier, (3) An Important barrier, (4) A very important barrier, (5) A barrier of most importance		
Problem	Score	Additional Notes
Low Yields/ Lack of improved cultivars		
Lack of Irrigation		
Poor management practices		
Market access		
Poor soil fertility		

Lack of credit		
Pests		
Susceptibility to Water Logging		
Lack of Available Land		
Labour constraints		
Extra Barrier 1		
Extra Barrier 2		

Extra Barrier 3		

Section 3J comparative assessment of crops grown				
Ask the farmers to comparatively assess Bambara groundnut to other crops grown *Note: comparatively assess crops performing a similar role to Bambara groundnut* *Fill in the crops* Crop A …… Crop B …… Crop C …….. Crop D …… Scoring system: (1) Best performer, (2) Second Best Performer, (3) Third Best Performer, (4) Fourth Best Performer Note: *If additional crops need assessed then adjust accordingly*				
Crop	1	2	3	4
Drought Resistance of Crop				
Resistance to Pests and Disease (in field)				
Resistance to Pests and Disease (During Storage)				
Crop Yields				
Susceptibility to Waterlogging				
Price Per Kg of Crop**				
Demand for crop				
Total Revenue from Crop				
Perceived nutritional value				
Taste				
Extra 1				
Extra 2				
Extra 3				
Extra 4				