

The competitive advantage of velvet beans as an economic agricultural commodity

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It all starts here™

"A world in which people are food secure is a world where all people have access to sufficient food to sustain a healthy and productive life; and where food originates from well-integrated, competitive, and low-cost systems based on the sustainable use of natural resources which will require a rapid increase in productivity and an increase in social investments"

(Braun & Keyzer, 2006).

TITLE:

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KEYWORDS:

Mucuna pruriens, competitive advantage, velvet beans, economical legume, agricultural commodity.

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ABSTRACT

The competitive advantage of velvet beans as an economic agricultural commodity. In the past 40 years, although food insecurity, poverty and environmental degradation persist, worldwide farmers have made considerable progress in increasing per capita food production whilst better understanding natural-resource management. Literature indicates that — in the decades to come — food demand will both grow and change for three reasons, namely increased numbers of people, increased income (people will have more purchasing power), and increased urbanisation (people will be more likely to adopt new diets containing animal protein and cereal). The world population is expected to increase to 8,9 billion by 2050, with 84% in the developing countries. Food insecurity and malnutrition are expected to persist despite progress on average per capita consumption of food.

As a complex system, and despite challenges, agriculture must produce simultaneously unprecedented abundance of food and unparalleled social concerns. As a business, agriculture requires high capital investments in land, facilities and production inputs; most often producing commodities of generally low unit value with thin profit margins, thereby forcing producers to strive for efficiency in all aspects of production. Therefore, it is of utmost importance that farmers should understand sustainable agriculture; where a more sustainable food-production system seeks to make the best use of nature's goods and services whilst not being harmful to the environment. Sustainable agriculture should maximise the productivity of the land; should focus on locally adapted resource-conserving technologies which assist whole system redesign and large-scale adoption; and should aim to minimise the use of harmful non-renewable and fossil-fuel derived inputs.

Fertilisers have not replaced the function of organic matter and other management practices; but soil erosion and toxic waste rather did increase disproportionately along with increased agricultural production. This has led to a progressive decline in crop and land productivity as a result of soil degradation, water contamination, increasing problems of weed infestation, pests and diseases. Often the apparent absence of sustainable productive agricultural systems within the scope of commercial farmers is not because of the lack in technology or low yield potential of traditional varieties, but rather on account of the limited knowledge or lack of awareness on the part of farmers about sustainable production practices which function in harmony with their farming environment.

As one of the keys to success the velvet bean — which can grow almost everywhere — is an example of the introduction of a simple regenerative component into a farming system, as well as boosting the capacity of a farmer for local adaptation of the technology. Integrating the natural

processes of nutrient cycling, nitrogen fixation and introducing natural enemies of pests into food production processes can contribute to minimising environmental damage and/or health of the farmer and the consumer. Using the knowledge and skills of farmers helps to improve their self-reliance and to solve a common management problem, such as social- and human-capital management.

The velvet bean is seen as an answer to the agricultural problem of low nutrient supply to the staple crop of maize. The bean creates ground cover, regenerates, fertilises the soil, controls weeds and adds organic matter and nutrients. In arid South Africa the crop is one of the strongest defences of the farmer against the harmful effects of El Niño — with the bean protecting the soil, holding water and fertilising the land with its leaves. With the velvet bean farmers can grow their own organic and inexpensive fertilisers. Commercial fertilisers are becoming more and more expensive and their benefit is decreasing because of a degrading soil resource base.

Furthermore, the rise in production costs makes total reliance on inorganic fertilisers more uneconomical for most growers in the agricultural sector; making it imperative for researchers to come up with options which increase the efficient use of fertiliser, and also to identify other nutrient sources — such as legumes — that are not capital intensive. The velvet-bean technique is known to researchers and farmers worldwide for a considerable amount of time, but not in our country. As the technique becomes better known to South African farmers, it can be considered in a broader sense as a modern way to add nitrogen to the soil; benefitting, amongst others, the subsequent crop. The velvet-bean approach has a window of opportunity which can lead to higher yields in crop production, decline in labour costs, crop diversification, as well as agro-processing — all resulting in improved food security for South Africa.

Adopting the velvet bean into a production system can benefit a farmer, by achieving maize yields of 3 t/ha–4 t/ha (similar to yields normally obtained with recommended levels of fertilisation at 130 kg N/ha) without applied nitrogen fertiliser or input for weeding. Velvet beans, as an intercrop, can provide more than 100 kg N/ha to the following crop. However, literature shows a declining trend over time for all systems, which suggests that additional external inputs (probably P and K fertiliser) are required to achieve full sustainability. The adoption of the velvet bean in the South African maize industry would result in import savings of about 158 million tons of urea or about R591 billion/year.

Information presented in this mini-dissertation is considered to be the current state of knowledge on establishing, managing, and utilising the velvet bean as a legume in South Africa's commodity

market; with the belief that it will expand the use of the bean, and will enhance the benefits from its use.

OPSOMMING

Die mededingende voordeel van fluweelboontjies as 'n ekonomiese landboukommoditeit.

Alhoewel voedselonsekerheid, armoede en agteruitgang van die omgewing voortduur, het boere die wêreld oor die afgelope 40 jaar aansienlike vordering gemaak in verhoogde per capita voedselproduksie, ten midde van 'n beter begrip van hulle beskikbare natuurlike hulpbronne. Volgens literatuur gaan die vraag na voedsel in die volgende drie dekades bly groei weens drie redes: hoër bevolkingsgetalle, verhoogde inkomste wat groter koopkrag beteken en verstedeliking, wat meebring dat daar 'n groter geneigdheid gaan wees tot 'n vleis-en-graan dieet. Verder word voorspel dat die wêreldbevolking gaan groei tot 8,9 miljard in 2050, waar 84% in die ontwikkelende lande. Ten spyte van die vooruitgang op die gemiddelde per capita-verbruik van voedsel, sal voedselonsekerheid en wanvoeding na verwagting voortduur.

Ten spyte van ongekende sosiale kommer en vele uitdagings, moet landbou as 'n komplekse stelsel tergelykertyd 'n ongekende oorvloed van voedsel produseer. As 'n besigheid, vereis landbou hoë kapitale beleggings, die fasiliteite asook produksie-insette; waar kommoditeitsproduksie meestal lae eenheidswaardes het met gepaardgaande lae winsmarges. Gevolglik word produsente gedwing om in alle aspekte van produksie doeltreffendheid na te streef. Daarom is dit van die uiterste belang dat boere volhoubare landbou moet verstaan — waar 'n meer volhoubare voedselproduksiestelsel poog om die beste gebruik te maak van die natuur se goedere en dienste, terwyl die omgewing nie beskadig word nie. Verder moet volhoubare landbouproduktiwiteit maksimeer wat gefokus is op plaaslik-aangepaste hulpbronbewaringstegnologie. Dit word aangehelp deur die produksiestelsel te herontwerp deur die bevordering van 'n verminderde verbruik van nie-skadelike hernubare en fossielbrandstof-afgeleide insette.

In die proses het kunsmis nie net die funksie van organiese materiaal en ander bestuurspraktyke vervang nie; maar ook gronderosie en giftige afval buite verhouding verhoog tesame met verhoogde landbouproduksie. Dit het gelei tot 'n progressiewe afname in oes- en landproduktiwiteit wat te wyte is aan die agteruitgang van grond, waterbesoedeling en toenemende probleme van onkruidbesmetting, peste en siektes. Hierdie oënskynlike afwesigheid van volhoubare produktiewe landboustelsels binne die bestek van kommersiële boere is dikwels nie as gevolg van die gebrek aan tegnologie of 'n lae opbrengspotensiaal van tradisionele variëteite nie, maar eerder as gevolg van beperkte kennis of 'n gebrek aan bewustheid aan die boere se kant oor volhoubare produksiepraktyke wat nie in harmonie met hul boerderyomgewing funksioneer nie.

As een van die sleutels tot sukses is die fluweelboontjie, wat byna oral kan groei, 'n voorbeeld van die bekendstelling van 'n eenvoudige regeneratiewe komponent in 'n boerderystelsel as lokale

aanpassing tot nuwe tegnologie. Met integrasie van die natuurlike prosesse van voedingstofsirkulering, stikstofbinding en natuurlike vyande van peste in voedselproduksieprosesse kan die fluweelboontjie bydra tot vermindering van skade aan die omgewing en/of die boer en die verbruiker se gesondheid. Met behulp van kennis en produksievaardighede kan boere gehelp word om hul selfvertroue te verbeter en gemeenskaplike bestuursprobleme op te los. Die fluweelboontjie word gesien as 'n antwoord op die landbouprobleem van lae voedingstowwe van mielies as stapelgewas.

Die fluweelboontjie bedek die grond, bemes die grond, beheer onkruid en berg organiese materiaal en voedingstowwe in die grond; sodoende kan 'n boontjieoes in dorre Suid-Afrika een van die boere se sterkste borswerings wees teen die nadelige gevolge van El Niño. Met die fluweelboontjie kan boere hul eie beskikbare en goedkoop kunsmis groei; dit terwyl kommersiële kunsmis besig om duurder te word en die gebruiksvoordeel daarvan besig is om te daal.

Die konstante stygings in produksiekoste maak die totale afhanklikheid van anorganiese kunsmis ook meer onekonomies vir die meeste produsente in die landbousektor. Dit noodsaak navorsers om opsies te ontwikkel wat doeltreffende gebruik van kunsmis verhoog, asook om ander bemestingstofbronne wat nie kapitaalintensief bekom kan word nie, te identifiseer. Die fluweelboontjietegniek is vir baie jare al wêreldwyd bekend aan navorsers en boere, maar nie in ons land nie. Sou dit beter bekend word aan Suid-Afrikaanse boere, kan dit gunstig oorweeg word in 'n breër sin as 'n moderne manier om stikstof tot die grond toe te voeg, wat op sy beurt weer die daaropvolgende oes kan bevoordeel. Die fluweelboontjienadering het 'n venster van geleentheid wat kan lei tot hoër opbrengste in die produksie van gewasse, daling in arbeidskoste, gewasdiversifikasie, sowel as landbouverwerking; alles wat kan lei tot die verbetering van voedselsekuriteit vir die land.

Die goedkeuring van die fluweelboontjie in 'n produksiestelsel kan 'n boer baat deur die bereiking van mielie-opbrengs van 3 t/ha–4 t/ha (soortgelyk aan die opbrengs gewoonlik verkry met aanbevole vlakke van bemesting op 130 kg N/ha) sonder toegepaste stikstofkunsmis of insette vir skoffel. Die voordeel is dat die fluweelboontjie, as 'n tussenverbouing, meer as 100 kg N/ha aan die daaropvolgende gewas kan voorsien. Literatuur toon egter 'n dalende opbrengstendens na verloop van tyd vir alle stelsels wat dus aandui dat verdere eksterne insette (waarskynlik P- en K-kunsmis) vereis word om volle volhoubaarheid te bereik. Aanvaarding van die fluweelboontjie binne die Suid-Afrikaanse mieliebedryf sal tot 'n besparing van sowat 158 miljoen ton ureum, of ongeveer R591 biljoen/jaar kan lei.

Inligting vervat in hierdie mini-verhandeling word beskou as die huidige stand van kennis op die vestiging, bestuur en die benutting van die fluweel boontjie as 'n peulgewas in Suid-Afrika se kommoditeitsmark; verder word geglo dat die gebruik van die boontjie sal uit brei tesame met die verbetering van voordele van die gebruike daarvan.

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LIST OF ABBREVIATIONS

BRICS	—	Brazil, Russia, India, China, South Africa
Ca	—	Calcium
C:N	—	Carbon:Nitrogen ratio
C/B analysis	—	Cost-Benefit analysis
DM	—	Dry Material
FAO	—	Food and Agricultural Organization of the United Nations
Foskor	—	Phosphate Corporation of South Africa
FYM	—	Farm Yard Manure
GDP	—	Gross Domestic Product
ICARDA	—	International Center for Agricultural Research in the Dry Areas
IFAD	—	International Fund for Agricultural Development
INRM	—	integrated natural resource management
K	—	Potassium
L-dopa	—	Levodopa
L-tyrosine	—	Levotyrosine
Mg	—	Magnesium
N	—	Nitrogen
NDP	—	National Development Plan
NGP	—	New Growth Path
NPK	—	Nitrogen, Phosphate, Potassium
P	—	Phosphate
PEST	—	Political, Economic, Social, Technology
SADC	—	Southern African Development Community
SAFEX	—	South Africa Futures Exchange
SWOT	—	Strength, Weakness, Opportunity, Threats
t/ha	—	tons per hectare
UNDP	—	United Nations Development Programme

CHAPTER 1: RESEARCH OVERVIEW

1. INTRODUCTION

Kaur (2012) states that organic farming is here to stay; declaring that this type of farming excludes the large use of synthetic inputs while relying extensively on crop rotations, crop residues and mineral grade rock additives; simultaneously combined with a biological system of nutrient mobilisation and plant protection. The World Wildlife Fund-SA (2009) is concerned about the South African agricultural sector which is dependent on applying sustainable farming practices to protect its long-term productivity and to ensure profitable yields and the well-being of farmers. Kaur (2012) also emphasises that the world today is driven by the sole motive of making money. He refers to the use of cheaper and alternative methods of crop protection, by employing cost-effective low-cost alternatives with the advantage that harmful chemicals do not enter into the food we eat.

Kate (2010) maintains that, after the Second World War, farming with chemical and herbicide inputs together with high-yield crop varieties boosted farming outputs in both developed and developing countries. Ogot (2012) sees competition as a war of movement which forces a farmer to respond quickly to changing market needs, with competitive advantage as the aim; the end result being to increase market share and profitability performances. Kaur (2012) maintains that organic farming is the only way which can ensure simultaneous quality and quantity of crop production, can reduce production costs for the farmer and harmless food for the consumer, and can ensure a healthier nation and more manpower.

According to Bowman and Zilberman (2013) — despite the shift of agriculture towards specialisation and mechanisation — a renewed vocal contingent is drawing attention to the social, environmental and economic implications of agricultural activities. They request a new production model to be envisioned. Bowman and Zilberman (2013) further state that evidence such as a production shift should be related closely to the concepts of sustainable, multifunctional and organic agriculture; with the aim to maintain critical ecosystem services.

According to the National Agricultural Marketing Council (2013), South Africa's current supply of oilseeds for commercial use is on a par with current demand; soya bean usage is mainly for human consumption and animal feed, and a projected total demand increase of 35,8% from 2012 to 2013 is indicated. Grain SA (2014) indicates that soya beans are the world's most important oilseed, accounting for double the volume of any of the eight most important oilseeds on the world market. In South Africa the most important oilseeds are soya and sunflower. *PULA IMVULA* (2011) highlights

that soya beans can also fix nitrogen, which is available as organic nitrogen to plants; and mentions that the value of imported seed oil amounts to R3,1 billion/annum.

1.1. Motivation to the study

Ostadi et al. (2013) assert that globalisation is a new circumstance which has limited economic development owing to eliminated trading limits; adding that when developing competitive capacity, the competitive advantage, national economic capacity and global market structures have to be evaluated. Njuguna (2009) states that, as determinants of business success, performance growth in competitive advantage and distinctive competence is the result of business sustainability; and pleads for business studies to be focussed on characteristics that are unique, adding value for the customer, and are transferable to different industrial settings.

Bechdol et al. (2010) suggest the pursuit of increased productivity will be a critical driver for change for diligent crop producers. They further declare that higher demand forces producers to increase yields at increased rates. The availability of new productive lands is limited, though, and therefore new technologies will be dependent both on economics of production and the willingness of society to accept such new technologies. Bechdol et al. (2010) list the four dominant forces reshaping crop production as growing and diversified demand, technology, resource availability, and societal influences.

1.1.1. Population growth

According to Go et al. (2013) the planning of a government lies in understanding demographic trends which are relatively stable over time, and which can be forecasted by a representation of the three drivers of population change namely fertility, mortality, and migration. Go et al. (2013) add that since 2010 the sub-Saharan region has experienced migration flows from within the continent to a country such as South Africa. These migrations are driven by changing economic, political and social factors which can result in large-scale changes in sheer numbers and directionality.

The World Wildlife Fund-SA (2009) states that the South African population increases by 2% per year. In consequence food production has to increase twofold, or production should be increased while using the same or fewer natural resources. Go et al. (2013) also comment that average life expectancy in South Africa has improved since 1960 and that this trend will continue.

- *Climate change*

McCarthy et al. (2011) maintain that the global community faces challenges such as climate change and food security; forcing agricultural production to improve with regard to production

systems as a means of food security and to improve income. Benin (2006) proclaims that domestic agriculture is the main source of food, which makes it a highly sophisticated and successful sector that is commercially orientated, capital intensive, and generally produces surpluses. Furthermore, McCarthy et al. (2011) state that the improvement of resilient production systems is essential for adapting to climate change; because of reducing crop productivities owing to adverse changes.

Baine (2013) indicates his concern about the effect of climate change on South Africa, which has half the average global rainfall. With 98% of water systems in crisis; farming and eating habits are changing, with decreased farmer profitability.

Benin (2006) states that, although agronomic and economic studies have been done on the impact of climate change, it is unclear what adaptations are available to Africa and how the continent will be affected.

- *Lifestyle and health awareness*

According to Crosswaite (2013) people are more interested lately in their holistic health and are increasingly encouraged to manage proactively the condition of their bodies. They are enabled to feed their sense of empowerment and engagement and a focus on the health experience is emerging. Alano (2014) argues that nowadays the world is busier with consumers continuing to change into eco-explorers; aspiring to back-to-nature living as reflected in their choices of lifestyle, healthier food and anti-stress methods.

According to Baine (2013) the population is growing and getting wealthier which adds to food security concerns; contributing to a rising demand for animal and fish proteins, fresh fruit and vegetables. Bradshaw (2008) states that sustainable environmental management needs more attention in terms of sustainable agricultural practises. The efforts of health information system improvement should be continued by linking health and development with better water, nutrition, and food security. Alano (2014) concludes that customers with a clinical disorder such as Parkinson's disease will turn to a diet which promotes health benefits such as improved cholesterol levels, better digestive and increased energy levels.

- *Food production practices*

MarcRobbins (2014) states that food contamination by pesticides, hormones, and chemicals allows us to have toxic foods; the result being that many suffer from obesity, diabetes and more chronic illnesses than ever. MarcRobbins (2014) also declares that a revolution is brewing beneath the surface with more and more people finding their voices and taking action in the belief that the

quality of food and the quality of their lives are linked; noting the growing demand for healthier food which is also becoming a political force where more people say 'no' to foods which lead to illnesses.

1.1.2. Agricultural sector

Karuna (2011) comments that agriculture has been associated with the production of basic food crops and is seen as a backbone of an economy and the population of a country; highlighting its role as a source of livelihood, supplying food and fodder, contributes to foreign exchange resources, offering employment opportunities, and can be the basis of economic development by providing necessary capital for other sector developments. According to Business Day Live (2014) agriculture in South Africa contributes 3% to gross domestic product (GDP) and 7% to formal employment. With strong economic links it allows the agro-industrial sector to contribute 12% to the local GDP and 6,5% of total exports.

According to the Department of Agriculture, Forestry and Fisheries (2012) farming remains important to the economy with 638 000 people formally employed while an estimated 8,5 million jobs are dependent on agriculture. The sector is considered to be capable to create jobs, therefore, it is the key focus of the New Growth Plan of the Government which aims to create 5 million jobs by 2020.

The Buro for Food and Agricultural Policy (2013) states that agriculture sustained its growth in 2012, fuelled by higher commodity prices and field crop production volumes. The Buro indicates that, with 2013 as baseline, the annual growth rate compared to the prior decade was lower because the marginal prices of commodities were protected and characterised narrower profit margins; with fierce competition among local market participants and international players, adding that narrower profit margins will be a challenge for the primary industry and the complete food value chains. The Buro for Food and Agricultural Policy (2013) suggests that the adoption of technology and sustainable farming practices can boost competitiveness, especially because South Africa is the main maize producer in the Southern African Development Community (SADC).

- *Agricultural land use systems*

Kassam et al. (2010) mention that the quest of agriculture to sustainability has coincided with rises in food costs, energy and production inputs, climate change, water scarcity, degradation of ecosystem services and biodiversity, and the global recession; adding that additional pressure is created by the demand of population growth on agricultural products, produced within a compatible ecosystem service. Vanlauwe et al. (2013) declare that principles of conservation agriculture had

originated with large-scale farmers in Brazil during the 1970s and have since spread to other countries.

Altieri (2002) emphasises that the improvement of whole farming systems should be based on the socioeconomic needs and environmental circumstances of farmers; although it might be a sensible avenue for solving the problems of poverty, food insecurity and environmental degradation. According to Vanlauwe et al. (2013) conservation agriculture is defined around the three principles of minimum tillage, soil surface cover, and diversified crop rotations; and they suggest that conservation agriculture should be promoted to help intensify sustainable farming systems within sub-Saharan Africa.

1.2. Competitive environment within South Africa

Wells (2014) defines the competitive environment as a dynamic external system in which a business competes and functions; stating that the higher availability of a similar product within the market place indicates more competition. Well (2014) asserts that the primary determinant of profitability is the appeal of the operational industry and the secondary determinant is the position of the firm within that industry; adding that either direct or indirect competitors motivate a business to be innovative in striving to outdo the indirect competitor.

1.2.1. Agricultural sector

According to Esterhuizen (2006) globalisation has caused agribusinesses to compete in domestic and foreign markets, thereby to introduce new customers and markets. The issue of competitiveness and comparative advantage has become important and implicates both society and business organisations. The Department of Agriculture, Forestry and Fisheries (2012) states that — over the past decade — the concept of competitiveness of the South African agribusiness sector has been redefined radically by policy and practice, where initiatives have been implemented to deregulate and liberalise further the sector to help promoting a free-market approach.

Esterhuizen (2006) proclaims that, at organisational level for sustainable financial relevancy and growth, the production and marketing of competitive products and services should be in an economical sustainable manner. According to the Department of Agriculture, Forestry and Fisheries (2012) free trade agreements reduced import protection. Although a harsh environment, the global regulatory environment presents the South African agribusiness with no other choice but to compete.

1.2.2. South African competitive business environment

SAinfo (2013) comments that South Africa is one of the most sophisticated and diverse emerging markets located as a continental gateway to Africa, with key investment market opportunities that lies within its borders. According to the New Zealand High Commission (2010) the South African Reserve Bank maintains independence from the government and the programme of inflation targeting, stabilises real interest rate, and encourages foreign investments, all showing good results with the currency remaining at competitive levels.

SAinfo (2013) adds that the country offers highly developed first-world economic infrastructure, an advanced and broad-based industrial and productive economy, and a disciplined fiscal framework which all aims at increasing the outward orientation of the the economy; with economic reforms given rise to macro-economic stability. As far as competitiveness is concerned, Walter Kluwer TAA Ltd (2013) states that South Africa was ranked 52nd out of 144 countries in the Global Competitiveness Index of the World Economic Forum for 2012; the highest ranked country in sub-Saharan Africa, claiming third place among the BRICS countries.

SAinfo (2013) further indicates that the key challenges of poverty, unemployment and inequality are still being faced; averring that the South African government is therefore trying to address these through two key economic frameworks, namely *New Growth Path (NGP)* and the *Industrial Policy Action Plan*. Walters Kluwer TAA Ltd (2013) also declares that the South African government provides incentives for value-added manufacturing projects, supporting industrial innovation, and provides an enabling environment for small business development.

1.2.3. Risk and price volatility

Kahan (2013) asserts that — as farmers evolve from subsistence farming to commercial farming — their decision-making is influenced by many unpredictable factors and **is** therefore more exposed to business risk. He also mentions the importance of understanding such risk and having the skills to manage it. The Food and Agricultural Organization of the United Nations (FAO) (2011) indicates that the supply side has scarce resource challenges as well as the decline in yield rates of some commodities; which possess substantial challenges to food being produced at affordable prices, further increasing food price volatility because of the strong link between agricultural and energy markets.

Kahn (2013) lists sources of risk as climatic, equipment breakdowns, borrowing money, and risk related to family wealth and the supply of labour. FAO (2011) adds that price volatility is context-

specific, and depends on the commodity being considered, the specific policy, and exchange rates; all affecting the circumstanced price transmissions.

Kahan (2013) summarises by pointing out that the attitude of farmers towards risk differs greatly, often related to financial ability. Risk management can be classified as

- i) *risk-averse*,
- ii) *risk-takers*, and
- iii) *risk-neutral*.

Kahan (2013) further mentions that good risk management decisions, such as choice of a crop, depend on accurate information which requires reliable data. FAO (2011) concludes that crop production has the potential to be increased through new technologies, improved extension, and/or by reducing losses in the supply chain.

1.3. Business management tools

Cohn and Hough (2008) state that the SWOT analysis is an essential tool for determining the position of a business entity in its market; helping to influence the business strategy used to capitalise on the resources of the company, opportunities and defences against competitive threats. Cohn and Hough also are of the opinion that the SWOT analysis scrutinises current and future situations within the market — the goal being to build as much as possible on internal environmental strengths and weaknesses — while reducing external environmental opportunities and threats; helping a business with a prepared plan to consider the option to attack a competitive weakness rather than a competitive advantage.

According to Jurevicious (2013) the aim of PEST is to understand better the overall surrounding of the business; to uncover the current external affecting factors, to identify those factors which can change in the future, and to exploit the opportunities or to guard against threats in a better way than competitors. According to Value Based Management (2014), for sustainable operations a PEST analysis can be used as a strategic framework and can play an important role in the value creation opportunity as a business strategy; concluding that macro-economic factors can differ per continent, country or region and should therefore normally be performed per country.

Jurevicious (2013) describes the elements as *Political* (such as minimum wages, tariffs and market regulations), *Economic* (interest rates and fiscal policy, while the economic climate dictates how consumers, suppliers and other business stakeholders behave), *Society* (family, friends, media, and population), and *Technology* (genetically modified seeds, and new production practices).

Deshpande (2008) considers a farming entity as a business entity as well and therefore believes Porter's model — to help analyse the external environment of the industry — is one of the best frameworks to create a complete picture thereof. He refers to the model indicating that — for any particular business unit — one internal force can determine the extent of impact of the other exposed four external forces. According to Boundless (2014) Porter's five forces draw on qualitative industrial business economics, and derives that the five forces determine the competitive intensity and attractiveness of a market; comparing profitability of the business and its position at the line of business.

Boundless (2014) considers the five forces as *threat of new entrants*, *bargaining power of buyers (outputs)*, *bargaining power of suppliers (inputs)*, *threat of substitute product of services*, and *rivalry among existing competitors*; and notes that the strategic implications of competitive forces indicated that the competitive environment is unattractive when rivalry is very strong, entry barriers are low, competition from substitutes is strong, and if suppliers and customers have considerable bargaining power. Rachapila and Jansirisak (2013) assert that inability to respond to rapid external changes is the cause of business recession; suggesting the utilisation of competitive forces to inspect competency and environmental instability, and designing a defensive plan against these rapid changes.

Deshpande (2008) further mentions that the agriculture specialists of the United Nations (International Fund for Agricultural Development [IFAD]) ran the Agricultural Marketing Systems Programme in Tanzania. This is a good example of the five forces model of Porter used as a basis for structuring poverty alleviation. Dobaria et al. (2011) state that the development of Porter's Generic Strategies of the five competitive forces has an impact on the profit of an organisation; thus new strategies have to be developed by enabling superior shareholder value to combat the forces strategically better than those of a rival.

Dobaria et al. (2011) label the three generic strategies as cost leadership, differentiation, and market focus or niche marketing. However, QuickMBA (2010a) warns that having more than one single generic strategy can leave a business at the risk of being *stuck in the middle* and not achieving a competitive advantage. Because customers often seek multidimensional satisfactions, each chosen generic strategy should have an attribute that serves as a defence against competitive forces.

1.4. Problem statement

The research problem relates to the following points of concern.

1.4.1. Escalating inputs costs of commodities

According to Van Schalkwyk (2008) food prices are expected to rise owing to smaller plantings from farmers as a consequence of escalating input costs. Kate (2010) states that the spurt in prices of fertiliser and fuel (46,8% and 60,7% respectively) has increased farm requisites by 21,6%, with overall farm debt growing by 18,5% — which accounts for almost 25,3% of the total farm assets used as collateral by farmers. Van Schalkwyk (2008) adds that the report of the South African Bureau for Food and Agricultural Policy has indicated an increase in input costs. Driven by oil prices, fertiliser prices have increased by as much as 400% since 2006, with combined input costs which have risen by 53% in 2008 and even more in 2009. Kate (2010) continues by stating that production costs have increased to beyond the value of farms, which indicates that few farmers will be able to survive crop failures. These higher production costs also have contributed to inflating food prices.

Based on the foregoing, Van Schalkwyk (2008) notes that escalating pressure on consumer expenditure and constraints on supplies will slow South Africa's economic growth; increasing input costs make it increasingly more difficult to farm. Kate (2010) concludes that the current crisis of higher production costs are governed by factors such as industrialisation of the food production system, indebted countries switching from food crops to cash crops, monopolistic control of value chains by multinational corporations, neglected natural resources, effects of climate change on droughts and crop failures, and the shift from food production to biofuels.

1.4.2. Health considerations and Parkinson's disease

- *Consumers' food safety*

Grace Communications Foundation (2014) defines sustainable agriculture as a process of farming techniques where food, plant and/or animal products are produced while the environment, public health, human communities, and animal welfare are protected without compromising the ability of future generations to do the same. With food security being described as a '*crisis*' in Africa, the FAO (2009) asserts that universal recognition of food safety is a public health priority and requires a holistic approach from production to consumption; adding that consumers are at risk owing to aspects of production processes which are exposed to a wide variety of agents within the food chain.

According to Brownstein (2014) studies have linked pesticides with the development of Parkinson's disease — a new study has found the dopamine processing gene ALDH as being susceptible to inhibition from pesticides. He adds that researchers have demonstrated that — for people with

certain genes —exposure to pesticides may increase the risk of developing Parkinson's disease two to six times more. Brownstein (2014) concludes that pesticides appear to trigger an effect on the ALDH enzymes which are all involved in processing the brain chemical dopamine. The FAO (2009) furthermore believes that farmers should apply good codes of production practices; adapting specific production and farming systems to help obtain stakeholder commitment to the food production quality assurance process.

- *Parkinson's disease*

The Parkinson's Disease Foundation (2014) defines the disease as a chronic and progressive movement disorder with symptoms that continue and worsen over time. The cause is unknown, but there is treatment available to manage symptoms, such as medication and surgery. According to the Foundation scientific evidence shows that the hallmark sign of Parkinson's disease are clumps of the protein alpha-synuclein — called Lewy bodies — whose intestines have dopamine cells, causing non-motor symptoms experienced by people with the disease. The National Institute of Neurological Disorders and Stroke (2014) maintains that a person with Parkinson's disease has abnormally low dopamine levels owing to dopaminergic neurons which have died. With low dopamine levels people find it harder to get things done or to control movement.

According to the Institute there is no cure at present, but a variety of medications can provide dramatic relief from the symptoms. Patients usually are supplied with levodopa combined with carbidopa, which delays the conversion of levodopa into dopamine until reaching the brain. The Institute further explains that, although levodopa helps about three-quarters of the cases, not all symptoms respond equally to the drug. According to Feedipedia (2014) the velvet bean has three main uses, namely food, feed and as environmental service. With edible young leaves, pods and seeds the bean is used as cover crop and feed legume. Feedipedia adds that pods and seeds can be ground into a rich protein meal and be fed to both ruminants and, in limited amount, to monogastrics. Bioweb (2011) states that the velvet bean is high in protein, carbohydrates, lipids, fibre, minerals and rich in novel alkaloids, saponins, and sterols.

Bioweb (2011) adds that, although seed extracts contain high concentrations of L-dopa (3,4-Dihydroxy-L-phenylalanine), concentrations of serotonin have also been found in the pods, leaves and fruits. The Herbal Healer Academy (2012) states that L-dopa is made from L-tyrosine — an amino acid naturally occurring in the human body — which is the immediate precursor of and converted to dopamine in the brain; which acts as a neurotransmitter that promotes enjoyment and interest in life. The Herbal Healer Academy adds that the most beneficial medical use of this supplement is in the treatment of the degenerative disorder of Parkinson's disease.

1.4.3. Land reform and rural development

About SA (2012) states that land is seen as a catalyst for poverty alleviation, job creation, food security, and entrepreneurship; therefore the Comprehensive Rural Development Programme (Act) is aimed at reducing poverty by creating vibrant, equitable and sustainable rural communities. According to Waeterloos (2013) the demise of many small commercial farming units is owing to the hard work required to grow crops in the harsh environment of South Africa which is predominantly suited to livestock production.

About SA (2012) says that the three key principles on which the Act is based are

- i) de-racialising of the rural economy for shared and sustained growth,
- ii) democratic and equitable land allocation and use, and
- iii) strict production disciplines that guarantees food security.

Waeterloos (2013) refers to the World Bank (2008) who emphasised the potential leverage that rural economies can provide in reducing poverty; by integrating opportunities of higher segments in the value chain and the expansion of agrobusiness or non-farm products and services, through re-use of fallow land and further development of the agro-industry.

Manjengwa (2006) indicates that natural resources management in Southern African countries has been largely technocratic; referring to land degradation being identified as fertile topsoil erosion, deforestation and desertification which are all critical environmental issues. Waeterloos (2013) adds that a number of private farms have been integrated into corporate farms where about 5% of the enterprises are responsible for half of the overall commercial production; maintaining that production has switched from grains to export commodities such as processed agricultural products. Manjengwa (2006) further states that the dominant paradigm of environmental degradation refers to land degradation and soil erosion caused by overcrowding in communal areas and inappropriate farming methods on commercial farms; indicating a prevailing solution as the application of new agricultural technologies such as new crop varieties.

Manjengwa (2006) concludes by saying that sustainable agriculture should focus on the trend of soil protection, biodiversity and consumer health with the imperative to be profitable — while being subjected to the same economic pressures which affects the complexes external agricultural environments worldwide. By analysing the above-mentioned trends a farmer can display the ability to earn price premiums on a commodity such as the velvet bean.

- *Primary question*

In the light of all the aforementioned, the primary research question can be formulated as follows:

As a legume, does the velvet bean have a viable economic competitive advantage within the South African agriculture?

- *Secondary question*

To address and answer this question the following secondary question can be formulated:

Which external market forces affect the (financial) viability of the velvet bean to obtain a competitive advantage in South Africa (i.e. SWOT and PEST)?

1.5. Motivation of the problem

According to Cherry (2014) motivation is the goal-orientated process that initiates, guides and maintains behaviour of a person; either extrinsic or intrinsic actions that involves biological, emotional, social and cognitive forces, and consists of the major components of activation, persistence and intensity. According to Van Niekerk (2013) about 8,5 million people are dependent on agriculture in South Africa, therefore the agricultural sector has been identified through the NGP of the government as a sector with significant potential to create jobs in smallholder schemes and agro-processing. With this in mind, the government has embarked in stimulating production by smallholders, with a special focus on rural areas and the former homelands.

Anon. (2011) argues that the agricultural policy and practice in South Africa has changed dramatically over the past few years. These require farm producers and agribusiness to position themselves as business-driven competitors in a less controlled 'free market' global trading environment. According to Anon. (2011) this new environment demands the reality for value-adding interaction within the supply chain; to meet these imposed challenges. Agricultural economics will have an important contribution pinpointing opportunities of the supply chain and the financial viability of new commodities entering the market, with the emphasis on the competitive advantage elements.

This study aims to contribute to the literature by disclosing some of the underlying roots of competitiveness and profitability of the velvet bean in South Africa's agriculture industry, by

- i) creating a cost advantage and revenue opportunity for legume farmers through crop diversification;

- ii) addressing and contributing to health concerns of consumers through healthier food production practises and in supplying a medicinal substance needed in the treatment of Parkinson's disease; and
- iii) supporting and contributing to the land-reform issue in the country by allowing for lower-cost production practises and offering an alternative legume to cash cropping.

1.6 Needs or research objective

1.6.1. *Mucuna pruriens or the velvet bean as a solution to the above-mentioned problems*

According to McGrath (2001) farmers in Guatemala and Honduras have discovered that the velvet bean could be used as a green manure to help rebuild soils quickly; declaring that the velvet bean is able to produce 150 kg of nitrogen, as well as contributing about 35 ton/ha of organic matter as natural compost in the soil. According to Ceballos et al. (2012), while presently being used as a traditional technology, the velvet bean is becoming better known; described and evaluated by researchers both in experimental fields and in parcels of farmers in various tropical regions of Latin America and Africa.

McGrath (2001) also states that a crop such as maize can benefit from released fixed nitrogen being available as a fertiliser, thereby helping to regenerate local economies by benefitting farm families who have adopted the practise of sustainable agriculture. McGrath (2001) further maintains that the velvet bean has been introduced to promote soil and water conservation practices, adding that the velvet bean is used in cropping systems — which include maize and soya beans — where the yield of maize has increased by 47% and that of soya beans by 83%. McGrath (2001) concludes that the 'magic' of the velvet bean is also appreciated in Benin, Africa which reports that maize yields have more than doubled.

According to the Tropical Plant database (2012) the velvet bean is an annual climbing vine, growing 3 m–18 m in height. It is indigenous to India and is known to be used in the traditional Ayurveda system for thousands of years. Tropical Plant database (2012) indicates that different countries use the velvet bean for different ailments such as treating pain, diabetes, infertility, to calm nerves, to lower cholesterol and as blood purifier.

To answer the research question formulated in Section 1.3, the main objective of this study is to analyse whether agriculture understands, and how it interprets the internal and external competitive environment of the velvet bean as an economic viable legume. The study consists of two main focus areas:

- As part of the 5C analysis, the focus is on the *Climate* section (PEST) where the external business environment is analysed to understand the existing South African agricultural sector; and by what method the velvet bean can viably enter this environment as a competitive new legume.
- A SWOT analysis is done by examining the concerns, challenges and developments in the South African agricultural sector and in what way the local commodity market is affected by these concerns, challenges and developments; to access the competitive advantage of the velvet bean in facing these factors.

1.7. Research method

To achieve the above-mentioned objectives of this study, a theoretical study of recent literature is required. According to *Business Dictionary* (2014), exploratory research is described as the investigation into a problem and/or situation to provide insights to a researcher with more detail where a small amount of information already exists. A variety of methods such as trial studies, interviews and group discussions may be used for the purpose of gaining that information.

1.7.1. Literature review

The research aims to provide an exploratory analysis of the internal and external environment for agricultural commodities; consisting of a literature study which is presented as a case study. During the literature study, the focus is on the competitive environment in which agriculture is operating, to identify and to highlight economic opportunity as well as financial viability of the velvet bean as a new commodity for agriculture in South Africa. Information on a PEST and a SWOT analysis, focusing mainly on the external environments of production, is gathered from textbooks and scientific journals, the Internet and other relevant publications.

1.7.2. Empirical research

The second phase of the study consists of creating various financial models where the information gathered on the biological nitrogen fixing capabilities of the velvet bean is analysed economically. Furthermore, a comparative production cost analysis between three legume species is done; highlighting the economic benefit of the velvet bean.

1.8. Chapter overview

This study follows the mini-dissertation route in accordance with the guidelines of the Potchefstroom Business School at the North-West University and is divided into five chapters.

- Chapter 1 — Research overview

This chapter addresses the background to the study and motivation of the topic actuality, demonstrating the relevance and need for the suggested study. It highlights the competitive environment of agriculture and the commodity market opportunities in South Africa. This is followed by the problem statement, research question and objectives; all setting the foundation for the rest of the study. Finally, the research methodology is explained briefly and summarised.

- Chapter 2 — Demands on agriculture for new development

This chapter reviews literature where the competitiveness, industry concerns, challenges and development of agriculture are examined.

- Chapter 3 — Velvet bean and assessing the competitive environment

This chapter reviews literature on the velvet bean and its uses within agriculture. Literature also explains the other tools that are used in the research:

- SWOT — Strength, Weakness, Opportunities, and Threats to highlight the factors considered for the internal and external competitiveness of the velvet bean;
- PEST — Political, Economic, Social, and Technology and the attributes to help shape the competitive advantage environment for new products.

This chapter further reveals the economic development within agriculture as well as a financial viability analysis of the velvet bean.

- Chapter 4 — Comparative advantage of the velvet bean

This chapter sets out cost-benefit calculations of the velvet bean as well as a comparative analysis between the velvet bean and two other legumes. An analysis of the answers gained evaluates the above-mentioned data, identifying the key success factors to contribute in evaluating the economic value of the velvet bean.

- Chapter 5 — Summary, conclusion and recommendations

Chapter 5 deals with the competitive advantage of the velvet bean entering the market. The information gathered from the literature is evaluated in conjunction with results from the overall study, together with knowledge gained during interviews. Lastly, conclusions, recommendations and scope for future research are made and limitations of the study are addressed.

"The thing with farming is that it's one of the few professions where you have a multitude of uncontrollable variables. You can't ever predict the weather from year to year or even day to day, so it's high risk. Sometimes it's scary to want to invest more into land or overextend yourself" — Windham focus group participant

CHAPTER 2: DEMANDS ON AGRICULTURE FOR NEW DEVELOPMENT

2.1. Introduction

The purpose of this chapter is to give the reader an overview of the development within agriculture. The stated literature refers to economic drivers of production changes, the challenges faced by producers to improve productivity and the factors that influence profitability. Altieri and Funes-Monzonte (2012) remark that the three elements of sovereignty should be displayed and enhanced in agriculture's production efforts; namely,

- i) reaching food sovereignty (the right of a consumer to have access to a sufficient quantity and quality of safe, nutritious and culturally appropriate food, enabling a sustainable healthy life),
- ii) energy sovereignty (having sufficient energy within ecological limits from appropriate sustainable sources), and
- iii) technological sovereignty (having the capacity to achieve food and energy sovereignty through the environmental services which are derived from existing resources in reaching agro-biodiversity).

According to Bowman and Zilberman (2013) the twentieth century brought changes in the agricultural economics of developing countries dominated by operational production methods, increased labour costs, and changes in agricultural policies. They add that improvement in commodity productivity and a move to more capital- and technology-intensive practices can play a part in heterogeneous production within Africa.

2.1.1. *Production possibilities and challenges*

- *African context*

According to Altieri (2002) World Trade Organisation policies forced developing countries into open markets and allowed dumping of overproduction from developed countries at dis-incentive prices; this at the cost of local farming producers who mostly lacked the benefits of mainstream agricultural technologies. According to the United Nations Development Programme (UNDP, 2008) the East Africa economies attract attention owing to a variety of opportunities; referring to nature-based products whose potential could be tapped to raise incomes and providing alternatives.

To benefit, Altieri (2002) declares that a natural-resource management approach can address poverty alleviation, food security and self-reliance, ecological management of productive resources, the empowerment of rural communities, and the establishment of supportive policies. The UNDP

(2008) mentions that this allows for significant potential in production, processing and marketing of cash crops, such as medicinal plants, through rain-fed and irrigation production systems.

The Economic Commission for Africa (2013) holds that challenges such as a lack of production credit, low product commercialisation, low productivity, inappropriate production technologies, and the degradation of ecosystems face the production, processing and marketing of dry-land products; leaving African countries vulnerable to commodity price fluctuations. The UNDP (2008) believes that the existence of key supporting policies can open up space for new development; also that the right policies can help serve as a launching pad for long-term diversification and competitiveness of new commodities in Africa.

- *South African context*

According to South Africa.info (2012) the country has a dual agricultural economy consisting of a well-developed commercial sector as well as a subsistence-based production sector. South Africa.info states that the country has seven major agro-ecological zones consisting from arid to semi-arid in the western areas and subhumid to subtropical humid conditions in the east. South Africa.info (2014) documents that the climatic regions allows for 12% of the surface of the country to be arable, while unreliable rainfalls accounts for only 22% of the available arable land considered by commodity farmers as high-potential land.

According to Hannon (2012) South Africa faces a future of uncertain land reforms and increasing pressure for expansion, although the country is agriculturally the most productive on the continent. Meyer (2014) argues that South Africa will continue to play a leading role in the African agriculture landscape, mentioning that this notion will depend on internal perspectives and its agriculture stakeholders.

Hannon (2012) also mentions that cereals and grains, of which maize dominates, are the mainstay of South African farming and account for more than 60% of farmed acreage, of which about 16,7 million ha are classified as potential arable land. AGINFO TRADING (2013) rates agricultural challenges and opportunities as issues ranging from market development, assessing global and domestic markets, understanding new value chains, and the upliftment of the rural poor and information provision.

Meyer (2014) remarks that climate change is becoming a greater inhibitor of yields and plays an ever-increasing role in crop choices and planting decisions; reality is that a challenge also offer an opportunity. According to Esterhuizen (2006), when a society fails in achieving competitive advantage, that society can have a low standard of living and can jeopardise their independent

political actions and economic destiny. Therefore, competitiveness can be supported and be increased by productivity and adaptability. However, Hannon (2012) adds that about 8 000 South African maize producers have delivered consistently volumes of grain by achieving higher productivity per hectare owing to good farm practice and the enthusiastic embracement of biotechnology.

2.2. Whole system management and sustainability

According to Brodt, Klonsky and Tourte (2006) farmers are part of their larger society and form societal values and goals within their cultural context, with the result that farm management varies and is recognised as a crucial factor of farm operations. Hazell and Wood (2008) are of the opinion that the sustainable approach of agriculture is focused on synergistic and integrated management technologies; in minimising the purchase of external inputs such as chemical fertilisers, pesticides and energy-consuming mechanisation. Brodt et al. (2006) add that, to understand biological-based farming alternatives, one must understand the spectrum of management styles which contributes to decision-making; and indicate that strategies used will depend on availability of physical and human resources as well as attitudes towards risk, family life, and future factors.

According to Hazel and Wood (2008) technologies such as zero tillage and crop rotations resulted in increased land productivity; thereby also increasing the profitability of modern inputs. Shennan (2008) states that sound and fundamental biotic interactions should be manipulated to eliminate the need for external inputs; adding that a sustainable farming system needs an acceptable level of production and resources on which productivity depends within the socio-economical, political and cultural contexts of agro-food systems. In this regard Brodt et al. (2006) categorise successful farmers as environmental stewards, production maximisers and networking entrepreneurs; which refers to what Shennan (2008) proclaims about a complex design and management that requires an understanding of diversity and disturbance at multiple scales, combined with species- and site-specific knowledge in search of providing the desired agro-ecosystem.

According to Thrall et al. (2011) biological organisation is influenced by trends of fragmentation and simplification of natural ecosystems, land-use changes, and global mixing of species. They also state that an approach such as reduced tillage can have predictable effects on soil biota, with benefits of crop growth and the enhanced ability in support of beneficial rhizosphere micro-organisms and the maintenance of water and air quality.

Van Cauwenberg et al. (2007) document that a sustainable agro-ecosystem must be grouped on environmental (water, air, soil, energy, and biodiversity), economic (maintenance, marketing and

financial), and social pillars (food security and safety, acceptable farming practices and cultural goods).

2.3. Underlying economical and environmental drivers of change in agricultural production systems

According to Schreinemachers, Berger and Aune (2007) the World Bank and other international institutions are emphasising especially soil fertility management for enhancing agricultural productivity within sub-Saharan Africa. With reference to lower fertility, agricultural productivity decreases return of investments, increased need for famine relief, and higher food prices.

2.3.1. Factors that influence the profitability of farming systems

Bowman and Zilberman (2011) assert that the emergence of agricultural systems are influenced by biological and geophysical constraints and how these constraints interact with crop properties, market conditions, farmer characteristics, and knowledge; adding that lenders tend to insist on collateral from borrowers. They maintain that the risk of higher collateral requirements will increase the cost to the borrower, together with a higher incentive to repay a loan.

According to Binswanger and Sillers (2002) collateral demand will be higher normally for small farmers — which indicates a higher cost of borrowing, because explicit terms are translated into higher risks. They state that the credit market may disappear from the supply side for farmers who do not own acceptable assets as collateral or do not have high debt equity ratios. Bowman and Zilberman (2013) directly refer to the impact of policies and regulations on profitability; relating that decisions to increase the income of a farmer, to reduce financial and physical risk, and to reduce effort while being enjoyable will all shape the production-cost functions in helping to determine the best profitable choice of crop.

Binswanger and Sillers (2002) highlight that collateral has three functions, namely

- i) increasing the expected return of the lender while reducing the expected return of the borrower,
- ii) transferring the risk of principal loss from the lender to the borrower, and
- iii) providing borrowers who have low disutility of default with a repayable loan incentive.

2.3.2. Dynamics and interaction of soil processes and decision-making on farming

- *Investment decisions*

Long (2013) argues that working in a variable environment with multiple-risk profiles and complex interactions can influence business; and indicates that farmers enjoy the farming lifestyle, and holds deep-seated values and beliefs around family property being owned for generations. According to Cole, Gine and Vickery (2011) high-yield crop varieties, chemical fertilisers and other modern cultivation practices were introduced by the Green Revolution; leading to tremendous increases in global agricultural productivity. Long (2013) maintains that — with effective and successful financial optimisation — a good manager should have clearly defined business and personal goals, where profitable decisions will be influenced by farming lifecycle stage, personality type, and stress levels; failure to account for these factors can lead to significant change as well as business failure.

Cole et al. (2011) add that, despite higher expected return rates of new technologies, unevenness of output from their impact is still being restricted by predominant farming practises in the developing world; owing to credit constraints and limited access to information. Cole et al. (2011) conclude that the riskiness of farming investment might contribute that risk adverse households in developing countries are unwilling to bear income fluctuations associated with such investments.

- *Production decisions*

Strauss (2005) declares that agriculture utilises different factors such as land, labour, raw material, and capital; leaving the sector faced with characteristics, choices and constraints within the interactional framework of the state of nature. According to Bokusheva (2014) one should distinguish between two factors which influence agricultural production development, namely technical efficiency and production risk. According to Strauss (2005) constraints have to be considered during decision-making processes where only feasible combinations of input levels can produce a given output; indicating that nature and technology constraints exhibit characteristics of being monotonic and convex; captured within the law of diminishing marginal product and diminishing technical rate of substitution.

With regard to input use, Bokusheva (2014) adds that the presence of liquidity constraints will influence production output and producer behaviour. Strauss (2005) further states that — although a farmer can choose what to produce — the amount of produce and the production method, and the time factor fundamentally influence production decisions; reason being that incurred costs are either fixed or variable. Strauss (2005) indicates that a farmer should recognise the relationship between profit maximisation and return to scale in such that the operations will become inefficient.

- *Biophysical model*

Dury (2011) argues that climate change forced agriculture towards higher levels of production, which occurs in a more environmentally concerned society; adding that the forced adoption of more innovative farming practices is fuelled by fluctuating crop prices combined with new regulations which also have changed the socio-economic context of farmers. According to Stephens et al. (2008) the biophysical model is an integrated bio-economic model that captures selective details within and between subsystems; dynamically reverse-linking the biological processes and feedback, and economic decisions made by farmers.

Dury (2011) adds that most farming systems are exposed to the sources of production risks, risks of the market and institutional risks; with all elements questioning the vulnerability of current farming systems and emphasising the need for evolution in cropping systems. Stephens et al. (2008) state that a farmer can determine changing returns to agricultural activities owing to the dynamics of biophysical resources. Through rules of decision-making the farmer can choose how best to allocate his resources over time, based on changing patterns in the returns to different activities with the outcomes of economic welfare.

2.3.3. Narratives of change

Hazell and Wood (2008) define a change driver as being a natural or human-induced factor that can bring change within an agricultural production system. Freibauer et al. (2011) proclaim that many of the present food production systems compromise the capacity of the earth to future food production, referring to foresight studies which found two narratives representing the two ends of the spectrum, namely a dominant or productivity narrative and the sufficiency narrative.

- *Productivity narrative*

Hazell and Wood (2008) refer to three scales of drivers which in turn are affected by interacted subfactors, all being listed as either global-scale drivers (affect agriculture worldwide to varying degrees), country-scale drivers (affect agriculture within a country although some factors such as infrastructure may lead to spatially differentiated influences), or local-scale drivers (specific to each local geographical area and different types of agricultural production system).

- *Sufficiency narrative*

According to Freibauer et al. (2011) agriculture is recognised as a vital component in natural resource management and emphasises a holistic and systems-based approach to knowledge production. They add that science needs to embrace a broader set of understandings by designing

farming systems that balance the various dimensions of sustainability from the outset. Tansey (2014) defines food sovereignty as the right of people to food which is appropriate, healthy and culturally produced through ecologically sound and sustainable methods; asserting that an agro-ecological approach helps to build biodiversity, to give the needed strength and resilience to maintain food and farming systems and justified societies.

Freibauer et al. (2011) conclude by asserting that the resulted operating system must differ significantly from current mainstream production systems by encouraging a different approach to farming practices, the natural environment, use of scarce resources and the ecological systems.

2.3.4. Factors influencing decision-making of farmers

Aune (2000) declares that decisions of farmers will have environmental consequences, regardless of what is being produced and what type of technology is being used; and notes that the sum of all decisions will determine the quality of the natural resource base. Aune (2000) categorises influential factors of decision-making into three classes (Figure 2.1.), namely political or economic frame conditions, household characteristics and the natural resource base; adding that economic conditions and the natural resource base will change stable production systems by influencing the system through price policies, interest rates, tenure legislation, extension and research.

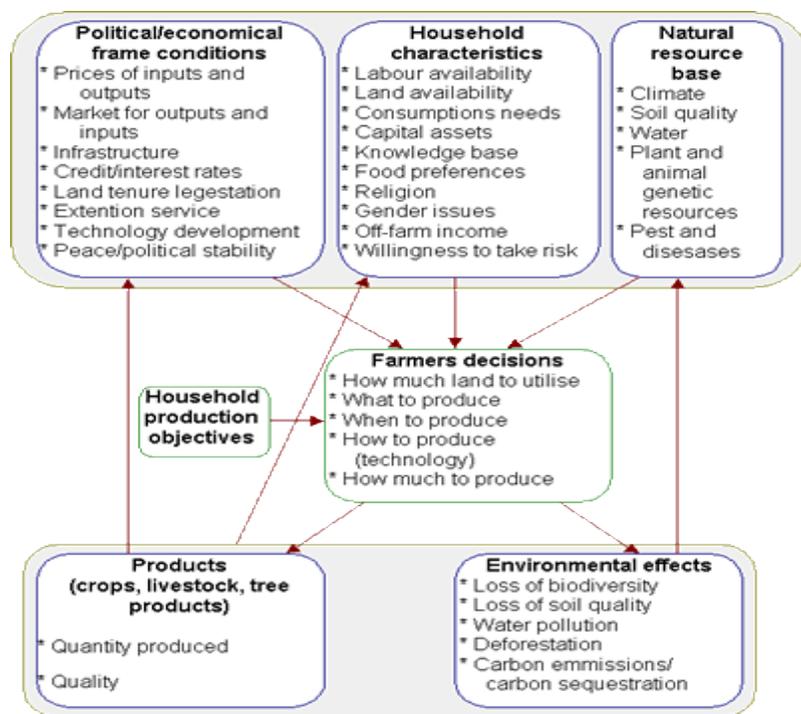


Figure 2.1 Factors that influence the choice of a production system in relation to the environment (Source: Aune, 2000)

2.3.5. Crop production profitability

According to Kate (2010) green revolution technologies lately have become discernible as a menace in the form of ecological and socio-economic influences and have proved to be severely negative for a country. According to Plant Nutrition Today (2013) farmers need to be flexible, and highlights the four primary factors which affect crop profitability as price, production costs, yield level, and quality; also stating that although producers are price takers they do have control over variable costs which in turn can have a direct influence on yield and quality.

Kate (2010) further declares that crop production costs have escalated dramatically, owing to the reduced efficiency of nutrient use; demanding increased fertiliser amounts, doses of costly pesticides and higher priced external inputs to help maintain productivity. Plant Nutrition Today (2013) states that the maximum economic yield concept therefore requires an optimised efficiency programme being designed to produce yields that can maximise profit while also exercising environmental stewardship.

Kate (2010) comments that the growth of input prices is not matched by product market prices which — in all — caused profits to dwindle and to be a grave for smaller farmers; adding that it is not an option to use fertilisers to reach sustainable food production levels.

2.3.6. Food security and increased yields

GRID-Arendal (2014) asserts that, although world food production has increased, food demand will increase owing to the further growth of the world population by an estimated 3 billion people; stating that food supply is a function of both production and energy efficiency, in the sense that food supply can increase without damaging the environment. According to the International Center for Agricultural Research in the Dry Areas (ICARDA) (2013) the high-performing food production systems of the world are using conservation agriculture to strengthen soil structure, fertility and improving water retention; bringing cost and labour savings to farmers for comparable yields.

The three factors listed by GRID-Arendal (2014) as the main contributing factors to increased yields are

- i) increases in larger crop- and rangeland area,
- ii) higher yield per unit area, and
- iii) greater cropping intensity.

ICARDA (2013) states that trials have shown that by combining minimum tillage practices, the retention of crop stubble and the use of crop rotations farmers can reduce production costs while

simultaneously achieving improvements in crop yields, soil health and nutrient recycling. GRID-Arendal (2014) attributes commodity yield increases of over 70% to both increased fertiliser applications and more water usages; but also maintains that yields have stabilised partly owing to lower and declining investments in agriculture.

2.3.7. Other land-use options

Verburg, Neumann and Anol (2011) declare that observable land use refers to the purpose for which land cover is exploited by humans as inferred activities from the structural elements of the landscape. According to Van Meijl, Van Rheenen and Eickhout (2006) trade ministers have agreed on a mandate for a new World Trade Organization which focuses on trade liberalisation, serving both development and the environment. The authors suggest that agricultural liberalisation can contribute to trade and growth and reducing poverty.

Verburg et al. (2011) also aver that land use is one of the driving forces of changes in earth systems which have caused the response practices of land management adaptation, aiming at reducing negative consequences of climate change. Van Meijl et al. (2006) proclaim that land can move into or out of agricultural production in what they consider as land mobility and availability, meaning that productive land is taken up firstly with limited potential to bring additional land into agriculture. The authors argue that land supply can be adjusted only owing to idling of agricultural land, conversion of non-agricultural land to agriculture, conversion of land to urban use and agricultural land abandonment.

According to the Food and Agricultural Organization of the United Nations (FAO, 2011) any further land expansion in Africa will depend on appropriate investment and might have negative environmental consequences. Whereas Van Meijl et al. (2006) state that a developing region such as Africa has obtained a high growth in total productive agricultural land use — which was driven mainly by food demand, macro-economic factors such as GDP and population growth. Busch (2006) is concerned that management of the natural resources of agriculture within rural areas is perceived by stakeholders and politicians as an integrative part of rural development; further increasing city migration, which will decrease agricultural employees and the abandonment of both farm holdings and agricultural land.

Busch (2006) adds that production demand leads to changed land-use requirements which depend on production technology, biophysical suitability and spatial restrictions of land resources.

2.3.8. Climate change

Lifson and Mitchum (2013) declare that climate change will result in a drop in agricultural productivity and increased food prices and argue that agriculture is set as the economic sector most affected by climate change. Seo (2012) asserts that economic studies are concerned about increased climate risks and their consequences, arguing that temperature increases will harm agriculture if climate thresholds for major staple crops are crossed. He adds that risk is a fact of life and that the decision-making of farmers goes with uncertainty and in consideration of risks, especially when financial returns are concerned.

Lifson and Mitchum (2013) further are of the opinion that a growing world population might lead to the difference between adequate food supply and food insecurity. They refer to research that has demonstrated developing countries' negative production effects from climate change — which implies that less nitrogen fertilisation is used, resulting in a challenge in creating effective adaptation strategies. Seo (2012) adds that, in sub-Saharan Africa, the highly considered climate risk lies ahead in the coming decades which will affect agriculture in the form of temperature and precipitation variability. Given uncertainties and soil conditions, a farmer will decide whether to specialise in crops or livestock, or to diversify into both production systems by choosing an agricultural system that earns a higher expected return than another.

Lifson and Mitchum (2013) argue that farmers have responded to climate change by altering input use downwards, by management practices on existing agricultural areas, and/or by expanding into new production areas. Seo (2012) also acknowledges that the decision of a farmer is affected by market and socio-economic conditions (distance to markets) as well as family characteristics (age, gender and education level) to which Lifson and Mitchum (2013) comment that the upward pressure on food prices will contribute to food insecurity risk and factors such as trade, land availability and demand.

2.3.9. Long-term challenges

According to the Food and Agricultural Organization of the United Nations (FAO, 2013) farm investment decisions are risky, owing to their long-term nature, with the outcome which consists of a risky sequence of net returns over the investment period. The FAO (2013) further declares that the conversion of these economic terms might be the basis of opportunity cost; stating that, by applying a discount rate for the problems, decisions are framed in the context of payoffs which constitute an annual stream of financial net returns assumed to be invariant over the life of the investment. FAO (2013) concludes that, given the complexity of decisions and the endemic nature of farm risk, the choices of the farmer must rely in part on his intuition and his subjective judgement.

2.4. Industry development and future trends

- *Integrated natural resource management*

According to Okuthe, Kioli and Abuom (2013) sub-Saharan Africa has acute food insecurity which is linked intrinsically with reversing stagnation and safeguarding the natural resource base. They state that major biophysical impediments to growth in African agriculture can be linked to declining soil fertility and low nutrient levels followed by land-use intensification without proper land management practices and inadequate external inputs. Wossen et al. (2013) indicate that productivity increases depend on the judicious management of factors such as natural resources, the adoption of new farming practices; focussed risk aversion and high opportunity costs, difference in agro-ecological and climatic factors, households' heterogeneity in terms of socio-economic characteristics and profitability factors.

According to Sridhar and Bhat (2007) developing countries have an important task in bridging the gap between teeming populations and food production. Economies are also influenced by livestock production, animal husbandry and the maintenance of soil fertility. Okuthe et al. (2013) state that this leads to the development and popularisation of integrated natural resource management (INRM) technologies as a continuing practice, that consequently helps to restore soil fertility within the shortest possible time. Okuthe et al. (2013) list the main components of INRM practices as fertilisers, manure, improved fallows, agro-forestry and green manures; all having the potential to improve soil fertility by increasing soil organic matter and biological nitrogen (N) fixation from nitrogen-fixing legume species.

Therefore, Sridhar and Bhat (2007) advocate the increase of legume-based pastures (many posing multiple uses such as food, fodder and pharmaceuticals) as an economically viable alternative for proteins and calories within developing countries. However, Okuthe et al. (2013) state that — for INRM to be successful — it is essential for farmers to understand, to adopt and to accelerate the practice to attain higher yields at lower costs.

Being adapted to adverse conditions, Sridhar and Bhat (2007) pronounce that wild legumes have been explored for their nutritional advantages to fulfil the demand of plant-based protein as an inexpensive and elegant source of protein, compared to conventional sources such as soya beans. Important to Sridhar and Bhat (2007) is the fact that — in view of rural development — the velvet bean has well-documented nutritional importance as a source of food, feed and as a pharmaceutically valued compound which provides symptomatic relief in Parkinson's disease; but also extensively being used as cover crop, mulch and in controlling agricultural weeds.

- *Conservation agriculture*

According to Kassam et al. (2009) the World Development Report 2008 shows that — in spite of unacceptably high environmental, economic and social costs — some agricultural systems still are being promoted as business-as-usual. Hobbs (2006) highlights the essence to use productive, but more sustainable, crop and soil management systems which help to improve soil health parameters (physical, biological and chemical) and to reduce costs of farmers; adding that the popularity of short-term solutions and immediate benefits — in terms of money and time — will always attract farmers.

Kassam et al. (2009) therefore state that conservational agriculture, in addressing the missing components in the intensive tillage-based standardised seed–fertiliser–pesticide approach, is promoted increasingly as constituting a set of principles and practices to make a contribution to sustainable production intensification.

Hobbs (2006) comments that technical and economic advantages of conservation agriculture can only be seen in the medium–long term when its principles are well established within the farming system; referring to the definite yield, economic and social benefits of no-till planting. Knowler and Bradshaw (2006) maintain that, although incremental costs accrue at farm level associated with adopting conservation agriculture, most of the benefits are captured by society; such as more regular surface hydrology, reduced sediment loads and increased carbon sequestration.

Hobbs, Sayre and Gupta (2008) state that the provision of an optimum environment in the root zone to maximum possible depth is the main criterion for conservation-effective agricultural systems, enabling roots to function effectively without restrictions to capture plant nutrients and water. Hobbs et al. (2008) also declare that soil life is complex and dynamic and is sensitive to tillage, pesticides and other toxins; which is why conservation agriculture takes advantage of biological processes in the soil to accomplish biological tillage in underground diversity, disease and pest suppression.

According to Knowler and Bradshaw (2006) the net financial impact of conservation agriculture appears positive as well, referring to where numerous financial analyses have shown that conservation agriculture produces higher net returns relative to conventional tillage; largely because of reduced costs for machinery, fuel and labour, combined with unchanged or improved yields over time. Hobbs et al. (2008) point out that conservation agriculture's multiyear rotational uses of different crops and cover crops with nitrogen-fixing legumes can provide a significant proportion of N; indicating that interactions between root systems and rhizobacteria can affect crop health, yield and soil quality.

Knowler and Bradshaw (2006) comment that the term '*environmentally profitable*' should be encouraged although the actual or perceived profitability of conservation agriculture can vary; adding that financial viability is an important consideration given biophysical constraints that may limit yields or institutional factors that may favour alternative practices. The view of Hobbs et al. (2008) is that conservation agriculture also poses some challenges, namely

- i) to overcome the mind-set of farmers in relation to changing the traditional tillage way of farming,
- ii) farmers having access to suitable machinery for planting no-till,
- iii) acknowledging that the full benefit of conservation agriculture will take time to appear with problems of initial transition years which may influence farmers to abandon this technology, and
- iv) convincing donors or governments who supply funds for research and development that the introduction of this technology takes time before being adopted by farmers.

- *Technology*

Wossen et al. (2013) argue that the future supply of food by smallholder agriculture is vital. It is dominant, forms about 80% of global land and supplies 60% of the staple food of the world. According to Ewert et al. (2005) evidence has showed that yields of a number of countries have approached a ceiling, with potential difficulty to increase further yields with present agronomic and breeding practices. Optimism for future yields increases will require advances such as technological development in agronomic and breeding techniques, though.

Therefore, it is the view of Wossen et al. (2013) that adoption of new technologies is essential to enhance agricultural productivity and food security; through reduced exposures to weather shocks. Hutchins (2013) states that the stability and productivity of agriculture will be influenced by the rate of development of technology as well as the degree of innovation; technology being classified as the development and use of nutrients, pest control products, crop cultivars and farm equipment. Referring to biotechnology, Ewert et al. (2005) suggest that yield progress is possible but that a biological limit will be approached leading to declining yield rates for the global economic scenario; adding that the a foregoing gives more scope for technology development in reducing the present yield gap, constituting owing to organic farming, reduction of the use of synthetic fertilisers and pesticides.

Also referring to technologies as being costly, Bowman and Zilberman (2013) mention that within diversified farming systems, the development of low-cost and practical strategies to reduce production costs is essential. According to Hutchins (2013), included in the vision of technology is

the premises of biotechnology (genetically created transmissions and physical adaptations) and precision agriculture (integrating information which enables management knowledge); also believing that the focus of Best Management Practices allows technology as an enabling man-made component to be used in remediating overused and misused agricultural land.

Bowman and Zilberman (2013) add that willingness from consumers to pay for such products needs education and campaigning awareness of ecological benefits; and they have the thought that producers should experience incentives for improved nutritional values of products, as well as having access to research and development funding to allow for such technologies to be applied within their diversified systems.

2.5. Agricultural dimensions

Montanarella (2013) declares that soil is more complex than water and air, is composed of inorganic and organic matter and points out that soil has, relevant to human life, main functions such as

- i) producing agricultural biomasses,
- ii) filtering, buffering and transformation activities to protect the environment through the food chain and drinking water reserves,
- iii) is home to biological habitats and gene reserves,
- iv) serves as a spatial base for technical, industrial and socio-economic structures and development,
- v) is used as a source of raw material, and
- vi) is a geogenic and cultural heritage for understanding the history of earth and mankind.

Montanarella (2013) warns that agriculture is based on the notion that soil is an inexhaustible resource for continuous production increases. Therefore, because soil is formed at a slow rate, it must be considered and preserved as a non-renewable resource.

- *Agricultural biodiversity*

The UK Food Group (2008) defines agricultural diversity as the direct or indirect use of a variable variety of animals, plants and micro-organisms for food and agriculture, and comprises diverse genetic resources and species; stating that in support of production it includes agro-biodiversity of harvested crop varieties and non-domesticated resources within field ecosystems, non-harvested species within production ecosystems (soil microbiota), and non-harvested species in the wider environment. According to Ikerd (2007) sustainable agriculture has critical and fundamental

prerequisites such as being ecologically sound, economically viable and socially responsible; declaring that all three dimensions of sustainability are inseparable.

UK Food Group (2008) adds that agricultural biodiversity is a result of practices, identified at different levels, used by culturally diverse people having spatial, temporal and scale dimensions; especially at agro-ecosystem levels which consists of practice factors of genetic resources, the physical environment, and human management. Ikerd (2007) argues that the sustainability approach excludes those not accepting agriculture as a legitimate human activity, those who see organic farming as the only means of achieving sustainability, those contending that an ecological sound system will adjust to social values and economic incentives, those who contend that a profitable system is sustainable, and those who contend that it is not necessary to provide economic incentives to a farmer who meet the needs of society over a period of time.

UK Food Group (2008) further states that interaction between these factors determines the evolutionary process; declaring that agro-ecosystems comprise poly-cultures, mono-cultures and mixed systems. UK Food Group (2008) refers to key functions for maintaining sustainable agro-ecosystems such as the breakdown of organic matter and the recycling of nutrients in maintaining soil fertility and sustainable plant growth, and the protection and conservation of soil. UK Food Group (2008) concludes that agricultural biodiversity is declining owing to the rapid expansion of industrialisation, relatively few crop varieties cultivated within mono-cultures and globalisation of the food and marketing system.

- *Soil fertility and yield*

The New Agriculturist (2014) indicates that all communities have identified land as the main limiting production factor; therefore fertility is built up through progressive and steady modification of the natural resource base with cropping following, selecting crop species and transferring crop residues. Hartemink (2006) maintains that — when growing agricultural crops — the nutrients in the soil are removed by the produce and residues, causing fertility to decline if replenishment with either organic or inorganic inputs is inadequate. According to the New Agriculturist (2014) it is quoted repeatedly that the evidence of decline in soil fertility stems from highly influential studies of land degradation in Africa, asserting that soil fertility is a fragile base to build expectations for increased crop production.

Hartemink (2006) defines soil fertility as the quality of soil which enables an adequate provision of nutrients in a proper balance for growing specified plants or crops; declaring that soil fertility decline includes nutrient depletion, nutrient mining, acidification, loss of organic matter and increases in toxic elements such as aluminium. According to the New Agriculturist (2014) the steepest decline in

soil fertility is where population and urbanisation increase the fastest; linking soil fertility to physical and chemical characteristics of the environment.

In conclusion the New Agriculturist (2014) states that, to maintain sustainable levels of crop production, Africa will require roughly three times more NPK-volumes than current usage; particularly nitrogen and phosphorus has declined to alarmingly low levels. Referring to the planting of legumes, which fix nitrogen from the air and transfer it to the soil, the New Agriculturist (2014) mentions that nutrient increases for follow-up crops can be achieved as such.

- *Crop productivity*

Edgerton (2009) asserts that global food demand together with accelerated use of grain for biofuel production have placed new pressures on grain supplies; stating that — to satisfy demand — two mutually exclusive options are available:

- i) increase the area under production, and
- ii) improve productivity on existing farmland.

According to Carr (2013) millions of small-scale farmers in Asia have shown that farm size is not the key determinant of productivity but rather that success is attributed to having access to intensified farming inputs, particularly to inorganic fertiliser; adding that the crucial issue for increasing productivity of farms in Africa lies in enabling farmers to obtain enough fertiliser to replace daily lost nutrients and giving farmers access to crops seeds which can best utilise those nutrients.

According to Edgerton (2009) increased productivity is preferred as it avoids greenhouse gas emissions and the large-scale disruption of existing ecosystems; adding that yield improvement is attributable to the development and the use of new farming technologies such as hybrid corn, synthetic fertilisers, farm machinery and introduced biotechnology traits. However, Edgerton (2009) declares that yield increases on existing agricultural land should be achieved incrementally through conservation tillage or transgenic insect control.

2.6. Constraint factors influencing profitability of agricultural systems

Salami, Kamara and Brixiova (2010) are of the opinion that, while some constraints are unique to a country, the smallholder agriculture in Africa has similar constraints which imply that common solutions would be possible. Salami et al. (2010) mention that some external constraints are not new but rather chronic to small- and large-scale farmers; and they divide constraints into two classes, namely:

- i) *Long-standing constraints to agriculture* (composed of subsections such as land management uncertainties, access to credit, access to input and output markets, agricultural extension and innovation, and climate change and related food-security challenges), and
- ii) *constraints related to the food and financial crises* (composed of subsections such as smallholder farmers in the context of the food crisis, implications of volatility in international fuel prices and implications of the global financial and economic crisis).

2.7. Economics of crop diversification in agriculture

The Department for Environment, Food and Rural Affairs (UK, 2007) asserts that a diversified farm economy can make a valuable contribution to business income and to the rural economy, adding that stakeholders view the enthusiasm of government for diversification with some caution. The only concern is that government regards diversification as an alternative to an efficient economically viable agricultural sector. Bowman and Zilberman (2013) state that farmers are typically risk-averse and that a diversified farming system can help maximise farm utility by

- i) mitigating different types of risks,
- ii) providing complementary inputs,
- iii) optimising production within biophysical or input and output market constraints, and
- iv) providing income benefits from ecosystem services or diversified farming system practices.

2.7.1. Economics of production

According to Duffy (2014) production costs will vary from farm to farm because of differences in soil potentials, quantity of inputs used and other factors; adding that input price shifts can change in both the short and the long run. According to Anon. (2014) the profound demand for products, rising production cost, advances in technology and uncertain government policies are all affecting the farmer. The complexity of these issues requires that the decision to management strategies and practises should be made in line with an understanding of economics and the risks surrounding it, the aim being to improve the bottom line of a farm business.

Lamm, Stone and O'Brien (2007) maintain that — within a cropping strategy — the yield capacity of a crop will depend greatly on the weather, the yield goal, and the economic conditions necessary for profitability. The authors add that because crops — such as corn, soya bean and legumes— are grown on dry land they often suffer in grain yields and economics. Duffy (2014) mentions that sufficient short-run cash income must be able to pay cash costs (such as seed, fertiliser, chemicals, insurance and labour) as well as machinery fuel, repairs and interest on operating capital; while

sufficient long-run income should pay all costs of profitable production for the resources used in their most alternative way or application.

Larsen (2013) declares that — since 1995 — global grain consumption dropped for the first time owing to higher prices, dampening the use of grain for ethanol production and livestock feeding. He states that although food consumption still does not exceed production; the concern is that with persisting droughts in key producing regions, farmers will be unable to produce the necessary surpluses to maintain global grain reserves ensuring food security. According to Sihlobo, Sundani and Fourie (2014) factors such as a weaker exchange rate, old season stock levels, weather conditions and higher food demand from Asia and Africa have increased the grain-market production and support new season prices.

Larsen (2013) also states that another production hindrance might be that farmers in certain areas have maximised productivity and are now running into biological constraints. At the same time, climate change enhances the likelihood of weather extremes such as heat waves, droughts, and flooding which can decimate harvests.

2.7.2. Crop diversification as effective tool in dealing with risk

- *Inter-cropping*

Machado (2009) defines inter-cropping as an ancient agricultural practice where a farmer plants two or more crops simultaneously on a single field; asserting that, with one of the four sub-category practices (mixed inter-cropping, row inter-cropping, strip inter-cropping and relay inter-cropping), a farmer can experience less risk when producing with inter-cropping, especially when having limited access to chemicals and equipment. Prins and de Witt (2006) state that, when the net returns of an intercrop become better than those of the sole crop, farmers will become more interested in the practice of inter-cropping; declaring that yield reliability, weed suppression, grain quality as well as economics will be important decision-making factors to a farmer.

However, Machado (2009) asserts that with mechanisation and cheap fertilisers and pesticides, the practice of mono-cropping has become the more “artificial” economic way to go; the necessity to grow a legume together with a grain in providing nutrients to the latter is more needed. Prins and de Witt (2006) also maintain that intercrops tend to have higher yield reliability than sole grains as well as the favoured effect of higher and profitable protein contents; stating that inter-cropping can be an organic solution to benefit arable rotations with nitrogen-fixing legumes and higher produced protein levels in grain.

Machado (2009) adds that the increased world demand for fertilisers has developed shortages, costs are escalating and environmental problems are becoming more known. Therefore, the sustainability of mono-culture becomes more apparent owing to the lack of a less diverse insect community and the fostering of weed problems. Matusso, Mugwe and Muchera-Muna (2012) state that, although inter-cropping is beneficial to farmers in the low-input or high-risk environment, the features of such a system differ with the soil, local climate, and economic situation, as well as the preferences of the local community. Machado (2009) affirms this by saying that — owing to these factors — the renewed interest in inter-cropping is increasing as part of a solution; especially if grain crops can be rotated with a legume, which may be a crop itself or may be grown as a cover crop.

- *Multiple cropping*

According to Skinner (2014) multiple cropping is an agricultural technique used to help maintain soil nutrient levels. He describes it as differing ways of growing more than one kind of crop in the same area; and refers to two ways of multiple cropping;

- i) relay cropping — starting one crop among another maturing crop, and
- ii) double cropping — where one crop is started after the growing season of the previous crop has ended;

declaring that both these practises are beneficial for replacing soil nutrients.

Matusso et al. (2012) also state that, despite the system having proved its success compared to mono-cropping, an important contribution is the ability to minimise measures against total crop failures and to gain different produces to be taken as income. Skinner (2014) mentions that these systems are beneficial because they help to reduce production costs, more nutrient-rich soil can yield better crops and soil moisture amassed by the first crop can benefit the second crop. He indicates that this agricultural practise can produce annually more than one crop out of the same soil. Matusso et al. (2012) point out that an important reason for inter-cropping is that increased and diverse productivity per unit area is obtained compared to mono-cropping. As an economic benefit, the system provides higher gross economic returns.

However, Matusso et al. (2012) mention that there are aspects to be considered in legume inter-cropping systems such as

- i) *maturity of the crops* — the largest complementary effects occur when component crops with different growing periods make major demands on resources at different times,

- ii) *compatible crops* — the correct crop combination to minimise not only spatially arranged plant competition, but also by combining crops to exploit soil nutrients,
- iii) *plant density* — adjusting the seedling rate downwards to optimise plant density, increasing yield because of less overcrowding, and
- iv) *time of planting* — studies have proven the effects of planting time on the performance of intercropping.

Matusso et al. (2012) conclude by mentioning that the system does have some constraints to overcome, such as soils that are acidic and that have limited phosphorus which lessens the N contribution of a legume component to the system.

- *Mono-cropping*

Patterson (2013) states that, although the mono-cropping system claims to be hard on the environment and less profitable than the organic means, planting one crop year after year can lead to specialisation with only the needed equipment to be purchased. According to Riche (2014) humankind does not learn from history, meaning that mono-cropping is increasingly dependent on pesticides and synthetic fertilisers. He refers to the three most popular crops as corn, soy beans and wheat, all grown with the mono-cropping method. The Global Environmental Governance Project (2009) declares that mono-crop systems often are accompanied by increased farm sizes and dependency on technology. Despite becoming more economically rewarding, the cultivation of a single species can stress fertile topsoil and can reduce genetic diversity.

Riche (2014) states that this is a blow to biodiversity where this system attracts large portions of land season after season, largely risking food security. He emphasises that soil is eroded and depleted of nutrients by overuse and crops are increasingly vulnerable to disease and natural disasters.

However it is averred by the Global Environmental Governance Project (2009) that such larger and intensified farming systems also lend themselves to greater waste production and higher greenhouse gas emissions as well as increasing plant susceptibility to disease as a single pathogen, potentially destroying an entire crop. Riche (2014) comments that, to create a sustainable food system, practises of biodynamic agriculture which uses natural ecology hold promise for creating regenerative systems that are less vulnerable to diseases; and pleads for a diverse food movement comprising farmers and community working together to establish a sustainable, safe and equitable food system.

2.8. Summary

In the chapter it is seen that farmers make choices to improve their utility or well-being. Those choices depend on economic choices about what and where crops are grown, what technologies are used, as well as other short- and long-term management decisions. This chapter highlights the fact that the twentieth century has brought changes in agricultural economics of developing countries. New World Trade Organisation policies have forced developing countries into open markets, allowing for natural-resource management approaches as possibilities into production systems.

South Africa — as an arid country — faces the challenge of climate change, through the enthusiasm of farmers who have embraced biotechnology and who have managed to deliver constant volumes of grain. This is achieved mainly by a focussed approach of synergistic and integrated management technologies which minimises external inputs; developing a sustainable agro-ecosystem around environmental, economic and social pillars. The reader is also briefed about the underlying drivers of production system changes, the role of collateral, investment decision drivers and production decisions which are both intertwined within a biophysical model and factors that influences decision-making of farmers.

It is also brought to the attention of the reader that integrated natural-resource management, including conservation agriculture and technology, can lead to productivity increase which in turn can contribute to food security. The reader is further warned that agriculture is based on the notion that soil is an inexhaustible resource for continuous production increases. Therefore, because soil is formed at a slow rate, it must be considered and preserved as a non-renewable resource. Sustainable agriculture has critical and fundamental prerequisites, too, such as being ecologically sound, economically viable and socially responsible —all three dimensions of sustainability are inseparable. It is pointed out that agricultural biodiversity is declining owing to the rapid expansion of industrialisation, relatively few crop varieties cultivated within mono-cultures and globalisation of the food and marketing system.

This chapter indicates that crop production causes fertility to decline if replenishment with either organic or inorganic inputs is inadequate; recognising the strong influence of human management practices such as tillage, continuously cropping the same land and limited crop rotation. It is mentioned that the planting of legumes can assist in higher crop productivity on existing agricultural land. The chapter concludes by taking the reader through the economics of crop diversification as well as the influence of price shifts on short-run cash income. The main focus of the latter part of the chapter is on risk which can be mitigated by inter-cropping and multiple cropping; especially if

grain crops can be rotated with a legume which may be a crop itself or may be grown as a cover crop.

The purpose of the next chapter is to introduce the reader to the velvet bean, its characteristics and beneficial usage in an agricultural production system.

"With the fertilizer bean, cowardly land becomes brave." Teodoro Reyes

CHAPTER 3: THE VELVET BEAN AND ASSESSING THE COMPETITIVE ENVIRONMENT

3.1. Introduction

This chapter introduces the reader to the velvet bean (*Mucuna pruriens*), sometimes simply called *Mucuna*, which is a trailing legume species capable of fixing atmospheric nitrogen, improves soil fertility and benefits crops grown after it. As such, it is suitable for farmers who have land that they can devote to grow the beans for a year.

Bunge (2014) states that, to support growing food demand, a balanced supply of plant nutrients can help to increase yields and to enhance the quality of the crop; also declaring that a plant will need mostly nitrogen (N), phosphorous (P) and potassium (K) to improve the growth of a plant, which adds up to a better harvest. Lloyd (2014) argues that the expanded use of legumes by present agricultural producers is mostly limited by a lack of experience and knowledge. According to Anon. (2010) successful nutrient management planning requires knowledge of farm system inputs; preventing nutrient loss as a source of environmental pollution, and loss of income through reduced yields or extra fertiliser applications.

According to Lloyd (2014) the velvet bean is used worldwide owing to its high nutritive value and its ability to use atmospheric nitrogen; remarking that legumes were a critical part of farming systems before the advent of low-cost nitrogen fertiliser after World War II. Anon. (2010) also maintains that proper nutrient management seeks to reduce these discrepancies in developing sustainable farming practices. Lloyd (2014) mentions that nitrogen fertiliser manufacturing is based on technology that requires oil and natural gas and as sources become limited, prices escalate; adding that the world appears to be on the verge of another energy crisis that will raise nitrogen fertiliser prices further. With proper management legumes can be used as an alternative to nitrogen fertiliser.

3.1.1. Historical use

According to Mulvaney, Khan and Ellsworth (2009) the use of legumes as a rotation crop or cultivation as green manure was a strategy used to

- i) replenish the used soil nitrogen, and
- ii) to provide organic matter necessary to maintain physical and chemical soil conditions, favourable for sustained crop production.

Ceballos et al. (2012) state that, despite the dominant trend of technology, farmers in the tropic region of Latin America have developed and have promoted the use of the velvet bean as a means to use agricultural fields sustainably; enabling them to grow various crops inexpensively in rotation and/or inter-cropping, thanks to the bio-control of weeds, pests and diseases while also preserving soil fertility.

Mulvaney et al. (2009) refer to work done by Tivy (1990) which states that agricultural intensification imposes a cost on the environment, as a result of

- i) increased soil erosion owing to soil exposure to weather effects,
- ii) ecosystem degradation and destruction which directly changes the physical environment,
- iii) usage of nitrate and phosphorous fertilisers that have polluted water bodies and aquifers, and
- iv) pesticides that have fostered development of pests and pathogens resistance and persistence which have affected wild bird species.

According to McGrath (2008) the use of the velvet bean has helped regenerate local economies across Guatemala and Honduras, benefitting some 47 000 farming families. He adds that some projects were so successful in productivity and production quantity that maize yields have at least doubled or tripled, which lead to increased land prices and labour rates with the result that families are moving back from the cities.

Yamada et al. (2009) assert that nowadays sophisticated technologies — such as heavy investment of input capital, high crop and animal yields and maximum efficiency — characterise modern and intensified agriculture; all demanding larger energy inputs for agricultural intensification, either directly (human and animal labour, fossil fuels and electricity) or indirectly (fertilisers, herbicides, pesticides, seed, water and other agrochemicals).

Yates et al. (2011) affirm that intensified modern agriculture began directly after World War II, about 40 years–60 years ago, with the collective technological development of the 'Green Revolution'; characterised by

- i) increased mechanisation of soil management,
- ii) increased use of fertilisers, insecticides, pesticides and herbicides, and
- iii) fast and widespread development of plant genetic improvement programmes.

3.1.2. Characteristics of the velvet bean

- Overview

According to Probst (2011) the velvet bean, known as a tropical legume mostly used as a growing crop and for its variety of medicinal uses, is classified as belonging to kingdom Plantae, class Dicotyledoneae, family Fabacea, and species *Mucuna pruriens*. Tropical Plant Database (2012) lists other common names for the velvet bean as being Nescafé, cowhage, cowitch, Bengal bean, Mauritius bean, itchy bean, *chiporro* and/or buffalo bean. Ceballos et al. (2012) pronounce that although the velvet bean is native to China and India, nowadays it is widely distributed in many tropical regions. Originally cultivated African varieties were introduced by humans along various commercial routes.

Pugalenthi, Vadivel and Siddhuraju (2005) report that the *Mucuna* genus includes annual and perennial plant species with vigorous indeterminate growth, which can produce vines of 3 m–18 m in length; and have a life cycle length from about 120 days–330 days. Pugalenthi et al. (2005) also remark that the leaves are trifoliolate and flowers are white to purple, arranged in hanging racemes 2 cm–3 cm long, pods are 5 cm–15 cm long with three to six seeds and are covered by a velvety pubescence, with seeds itself 1 cm–2 cm long, 5 cm–6 cm thick, and with a cream or bright black or mottled brown colour; the plant has numerous roots which can be 7 m–10 m long with abundant nodules near the soil surface. According to Bachmann (2014) the plant prefers an equable temperature of 20 °C–30 °C, requires a frost-free period of 180 days–240 days, and an average rainfall of between 100 mm/year–1 500 mm/year.

Bachmann (2014) states that optimum yields can be achieved in sandy loams, but listed soil requirements into

- i) *physical* (not waterlogged, wide array of well-drained soil, including heavy clays), and
- ii) *chemical* (tolerant to acid soils, optimum pH between 5–6,5).

Pugalenthi et al. (2006) maintain that a plant can accumulate 2 t/ha–10 t/ha of dry material and produces between 0,24 t/ha–6 t/ha of seed; mentioning that the velvet bean grows better in a warm humid climate and prefers night temperatures of above 21 °C to promote flowering. However, Pugalenthi et al. (2006) mention that the velvet bean plant is sensitive to frost during the growing season, does not tolerate excess moisture, but shows good drought tolerance once established.

- *Dry material production or mineral composition*

According to Pugalenti et al. (2006) the dry weight composition of the velvet bean of green forage, pods and seeds are as in Table 3.1.

Table 3.1 Dry weight composition of the velvet bean

Compound (%)	Foliage	Dry pods	Seeds	Seeds (Sahelian, 2014)
Protein	10,8–23,5	13,4–18,1	19–37,5	20–29
Fat	2,1	4,4	4,7-9	6–7
Moisture	–	10	10	–
Nitrogen-free extract	48,6	–	51,5	–
Fibre	19,3	–	–	–
Ash	14,9	4,2	2,9–5,7	3
Digestible protein	10,7	13,4	–	–
Digestible carbohydrates	49,6	–	–	50–60
Total digestible nutrients	63,4	73,8	81,7	–
Raw fibre	–	13	5,3–11,5	8–10

(Source: Author)

With regard to the dry mass accumulation of the velvet bean, from various research results the following yields have been recorded, as shown in Table 3.2.

Table 3.2 Dry material yield (t/ha) of the velvet bean (*Mucuna pruriens*) achieved in a rotational production system with maize

DM (biomass) (t/ha)	Location	Reference
7,4 – 10,2	Florida, USA	Wang et al. (2009)
9,9 – 10,6	Vihiga, Kenya	Kiwia et al. (2009)
3,7 – 9,8	Limpopo, South Africa	Odhiambo et al. (2011)
1,6 – 9,8	Limpopo, South Africa	Odhiambo et al. (2011)

(Source: Author)

From the table it can be concluded that dry material accumulation produces average yields of 7,8 t/ha, with 10,6 t/ha maximum and 1,6 t/ha minimum.

Pugalenthi et al. (2006) indicate that the seed of the velvet bean contain the minerals tabled in Table 3.3 and assert that among amino acids found, the aspartic (8,9%–19%) and glutamic (8,6%–14,4%) acids are predominant.

Table 3.3 Velvet bean seed mineral composition

Mineral	Value (mg/100 g)
Potassium	778–1846
Calcium	104–900
Iron	1,3–15
Manganese	0,6–9,3
Zinc	1,0–15
Copper	0,3–4,3
Magnesium	85–477
Phosphorous	98–498
Sodium	12,7–150

(Source: Author)

- *Seeds*

According to Karunanithi et al. (2012) the seed of the velvet bean, rich in L-dopa content, is one of the important herbal drugs in the Siddha, Ayurveda and Umami systems of medicine. The seed is sold in drug stores and is used both as food and as medicine for many other common diseases. Karunanithi et al. (2012) affirm that an analysis of such seed indicates the presence of 43 compounds in total (Table 3.4.); with the noted important phytoconstituents of tocopherol, ricinoleic acid, and derivatives of glucopyranoside and aziridine. Karunanithi et al. (2012) conclude that hydroalcoholic extracts of all the velvet bean seeds have shown no significant paralytic activities if compared to a standard drug.

Table 3.4 Analysis of velvet bean seed

S. No	Peak Name	% Peak area			
		MC	MD	MP	MU
1	2,4-Dihydroxy-2.5-dimethyl-3(2H)-Furan-3-one	0,62	–	2,02	1,02
2	3-Acetylthymine	1,86	1,11	1,8	–
3	4H-Fyran-4-one,2.3-dihydroxy-6-methyl-	1,36	0,74	1,73	1,48
4	4H-Fyran-4-one,3.5-dihydroxy-2-methyl-	0,04	0,02	0,09	0,08
5	1,2-Benzonediol,4-methyl-	0,12	0,05	0,23	0,10
6	Sucrose	6,3	–	5,6	6,63
7	Ethyl α -d-glucopyranoside	59,06	32,59	53,17	47,38
8	3-O-Methyl-d-glucose	1,3	2,46	0,58	0,85
9	p-Arbutin	0,18	1,10	–	0,37
10	Hexadecanoic acid, methyl ester	1,98	–	2,71	16,12
11	n- Hexadecanoic acid	2,33	1,11	3,69	–
12	Hexadecanoic acid, ethyl ester	3,08	8,29	2,90	1,91
13	9,12-Octadecadienoic acid, methyl ester	3,86	0,07	7,68	3,54
14	Palmidrol	1,32	1,70	–	2,13
15	9,12-Octadecadienoic acid, ethyl ester	3,95	2,82	5,32	2,16
16	Decanamide, N-(2-hydroxyethyl)-	0,22	0,17	3,02	2,07
17	Hexadecanoic acid,2-hydroxy-1-(hydroxymethyl)ethyl ester	2,38	1,67	–	1,54
18	Vitamin E	–	–	0,56	–

(Source: Karunanithi et al., 2012)

According to Pugalenthil et al. (2006) the seeds of the velvet bean also contains anti-nutritional factors such as total free phenolic, tannins (3,1%–4,9%), L-dopa (4,2%–6,8%), lectins (0,31%–0,71%), protease inhibitors (trypsin and chymotrypsin), phytic acid, flatulence factors (oligosaccharides), saponins (1,15%–1,31%), hydrogen cyanide (58 mg/kg) and alkaloids; concluding that seemingly the seed of the velvet bean constitutes an underutilised but valuable food resource in tropical regions. Firstly the toxic compounds have to be eliminated or to be reduced through conventional methods or by breeding *ad hoc*-cultivars.

Bachman (2014) report that unsaturated oil present in the seeds has been found to be 47,2% linoleic acid, 14,2% oleic acid, 3,8% linolenic and 0,5% palmitoleic acid; the saturated fatty acids as palmitic 19,5%; stearic 12,6%; and arachidic 2,2%, adding that trials shown that the toxic principle occurs in the protein fraction of the seed and not in the oil. According to Tuleun, Carew & Patrick (2008) the seed of the velvet bean has nutritional potential as a source of protein (23%–35%) and metabolisable energy of about 1 kcal/g for raw seeds and 3,2 kcal/g for processed seeds. In several African countries the seed is used as a minor food crop (as vegetable), a condiment, or as garnish for the main dish; given its nutritional potential if compared to other edible grain legumes (cowpea, soya bean, and ground-nut).

Tuleun et al. (2008) disclose that the seed of the velvet bean shows high contents of nitrogen and good essential amino acid levels, suggesting that it could serve as a source of essential nutrients to livestock on the basis that adequate information on the chemical composition of the seed is a prerequisite for its effective utilisation in animal nutrition. Bachman (2014) concludes by saying that, in addition to L-dopa, a new amino acid (-)-1-methyl-3-carboxy-6, 7-dihydroxy-1, 2, 3, 4-tetrahydro-isoquinoline has been isolated recently from the velvet bean.

- *Resistance or tolerances*

Zaim et al. (2011) claim that, owing to its content of 3-4-dihydroxyphenylalanine (L-dopa) and N,N-Dimethyltryptamine (DMT) within the leaves and seeds, the velvet bean is resistant and tolerant to many pests and diseases; providing a chemical barrier to insects and small mammal attacks. However, Zaim et al. (2011) indicate that the velvet bean is vulnerable to attacks from factors as listed in Table 3.5.

Tabel 3.5 List of soil factors that attack the velvet bean

Fungi	Bacteria	Virus	Nematodes
<i>Cercospora stizobii</i> , <i>Mycosphaerella cruenta</i> , <i>Phyllosticta mucunae</i> , <i>Phymatotrchum omnivorium</i> , <i>Phytophthora dreschleri</i> , <i>Rhizoctonia solani</i> , <i>Sclerotium rolfsii</i> and <i>Pestalotiopsis versicolor</i>	<i>Xanthomonas stizolobiicola</i> , <i>Pseudomonas stizobii</i> , <i>P. syringae</i> and <i>Striga gesnerioides</i>	Bean common mosaic virus, Bean pod mottle virus, Bean yellow mosaic virus, Cowpea mosaic virus, Soya bean mild mosaic virus, Soya bean mosaic virus, Soya bean stunt virus, True broad bean mosaic virus, Tobacco ring-spot virus, Tobacco streak virus, Watermelon mosaic virus-II, and Velvet bean severe mosaic virus	<i>Meloidogyne thamesi</i> , <i>M. hapla</i> , <i>M. incognita</i> and <i>M. javanica</i>

(Source: Author)

3.1.3. Velvet bean as a means for sustainable soil use

Olorunmaiye (2010) state that the recent African attention into legume cover crops is because of

- i) the unavoidable depletion of fossil fuels and increased nitrogen fertiliser costs,
- ii) traditional intensive farming systems that degrade the biosphere, and
- iii) the unsustainability of the traditional farming system owing to population growth.

According to Williams (2006), since the beginning of agriculture there was interest in the use of cover crop legumes to preserve soil fertility for crop production. The author refers to China and Japan where the use of cover crops and incorporated green manures has been documented since more than 3 000 years ago, whereas Greece, Rome and Mesoamerica have used it as a common practice under conditions of cheap labour, water restrictions and a lack of inorganic fertilisers. Mulvaney et al. (2009) declare that, since the 1940s, without considering sustainability and/or environmental impact, most economic policies were based on the wide availability of relatively cheap fossil fuels and chemical fertilisers which encouraged maximum-yield production systems. Consequently applied-fertilisers production could not replace the function of organic matter and other management practices, but contributes to increased soil erosion and toxic waste which lead to a progressive decline in crop and land productivity owing to increasing problems of weed infestation, pests and diseases.

According to Ceballos et al. (2012) several authors have described various worldwide farming systems which include the use of legume cover crops as a rotation, inter-cropping or in association with other crops such as maize and sorghum. Ceballos et al. (2012) also agrees with Olorunmaiye (2010) who remark that the use of legume cover crops (*Mucuna* spp.) has recently drawn attention in continents such as America and Africa.

In addition to the above, Ceballos et al. (2012) further add that legume cover crops (*Mucuna* spp.) are, apart from contributing to the reduction of soil erosion and weathering, also attractive for the bio-control of weed, pests and diseases in soil. According to Pretty (2000) the effectiveness of the velvet bean has been widely promoted in Central America, attested by its spontaneous spreading without outside intervention. Therefore, with a renewed view to intensified small-scale farming, fluctuating agricultural systems and other changing production circumstances may open up new opportunities for legume cover crops in the African region. Pretty (2000) also assert that the velvet bean exhibits reasonable tolerance to various abiotic stresses, such as droughts, low soil fertility and high soil acidity. Consequently, the velvet bean has been grown as a fallow crop to improve soil fertility, as a smother crop to control weeds, and as a forage plant.

Pretty (2000) announces that, in rotation with maize-production techniques, reports in Mesoamerica indicate better yields and higher net returns than those gained from maize-production practices based on commercial fertilisers, suggesting that cultivating cereals and legumes crops together can improve total yields and production stability; which concludes that changes in land-use patterns may have an effect on the use of the velvet bean — an issue that also emerges in northern Honduras.

3.2. Benefits of the velvet bean

Wang et al. (2009) maintain that, from the Americas to Africa, the use of the velvet bean as traditional technology is becoming better known by both researchers and farmers; acknowledging the advantages and benefits which can be obtained in the biological control of weeds, pests and diseases, and maintaining of soil fertility by the use of the velvet bean as a rotational crop. McGrath (2008) mentions that the velvet bean also has been introduced to Brazil where farmers have tested the plant as green manure and as a cover crop within maize, soya bean, and wheat cropping systems. In most cases the labour cost was kept down because of no need to plough the land for weed control.

McGrath (2008) also asserts that, as in Mesoamerica, the use of the velvet bean together with a range of soil conservation strategies have increased maize yields by 47%, soya by 83% and wheat by 82%; adding that this technology has also recorded improvements in water quality, soil health

and water retention. According to Lloyd (2014) nitrogen is the most limiting nutrient for plant growth, as well as the most expensive of the three major nutrients; indicating that about sixteen thousand cu. ft. of natural gas is required to produce one tonne of ammonium nitrate. Lloyd (2014) affirms that fertiliser companies renew their contracts for natural gas at higher prices, increasing nitrogen fertiliser prices; this makes legumes an important component of profitable farming systems by reducing production costs and labour.

Lloyd (2014) concludes by commenting that legumes have higher nutritive value by being easily digestible and higher in protein, calcium, phosphorus, and magnesium. Lloyd (2014) adds that legumes also provide spring weed control through plant competition, which reduces the need for herbicides. Legumes are more environmentally friendly because they do not require commercial nitrogen fertiliser that can leach into ground water.

McGrath (2008) further reports that the potential of the velvet bean is also appreciated in Benin (Africa) and mentions that, since being introduced to 15 farmers in 1987, the velvet bean has been used by over 10 000 farmers (2000). Once again extension workers report that maize yields have more than doubled.

3.2.1. As a crop

Bachman (2014) discloses that various velvet bean cultivars exist, suitable for more humid regions of the tropics, while others are suitable for dry-land farming; also stating that — although the velvet bean can be grown successfully on soils unsuitable for cowpeas — the beans have the disadvantage of a longer growth period and are more difficult to thresh, but still the leaves and vines make excellent fodder.

- *Green manure or cover crop*

According to Odhiambo (2011) organic matter content within the soil can be improved through the use of green manure. It helps to improve the structure of the soil, pore size, water-holding capacity and efficiency in organic fertiliser use by increasing the cation exchange capacities. Ceballos et al. (2012) define green manure as soil incorporated, green or before reaching maturity, herbaceous or woody plant material that is grown either *in situ* or *ex situ*. The aim is to maintain and/or improve soil fertility.

Ceballos et al. (2012) note the existence of several forms of applying green manure to soil, namely

- i) simultaneous cut and burial,
- ii) cut and scattering over the soil surface,

- iii) incorporation of produced material and harvested at another field, and
- iv) as a compost.

Mureithi (2011) declares that agricultural conservation can be enhanced by the use of green manure legumes to help improve farm productivity, by providing ground cover which minimises soil erosion. Because legumes are fast growing they accumulate high biomass within a short period. Legumes increase the plant nitrogen supply of the soil through biological nitrogen fixation with resulted increases in crop yields.

Odhiambo (2011) remarks that the velvet bean has been screened as one of the most suitable legume cover crops for the Limpopo region in practicing inter- or relay cropping with maize; also adding that green manure legumes used in combination with N-fertilisers have the potential to increase the maize yield of smallholder farms. Mureithi (2011) further announces that legumes are deep rooting which improves soil structure and nutrient recycling, are an important source of human food and livestock feed and even smother weeds; thereby reducing labour needs for weed control.

Kaizzi et al. (2014) maintain that, through mineralisation by soil microbes, plant tissue N is converted into nitrates; allowing for an average of 50% of the total N contained in the cover crop being available to the subsequent crop. Klassen et al. (2006) mention that the velvet bean has the important morphological attribute of a high proportion leaf to total above-ground weight, which is about 62% at time of bloom; this higher percentage of leaf tissue allows for more immediate release of N for use by the subsequent crop. Kaizzi et al. (2014) also assert that legumes have relatively low C:N ratios, meaning that legume N can be mineralised quickly within two weeks after soil incorporation — before the subsequent crop has a high demand for available nitrogen.

Klassen et al. (2006) further affirm that another attribute is its large petiole, normally having nutrient concentrations of about three times greater than in the leaf blade itself; mentioning that petiole extracts are more toxic to the root knot nematode than other plant parts, and recommend that the velvet bean should be, as a green manure, be terminated and soil incorporated no later than two weeks after the first blooms.

Kaizzi et al. (2014) suggest that a synchrony of N release from decomposing legume residue and crop N demand can increase the overall efficiency of use by timing of cover crop kill; as general, the more mature the cover crop, the higher the C:N ratio and the slower the decomposition.

Jiri (2012) reports that — with a dense canopy — the velvet bean becomes self-shading, with fallen leaves which may contribute to substantial amounts of N; claiming that 50%–70% of N in legume tops is derived from fixation. Jiri also reveals that fixation ranged from 20 kg–25 kg N/t dry matter,

regardless of species, soil and environment. Mureithi (2011) further argues that higher maize yields are obtained if green manure is combined with inorganic fertilisers. It also saves on inorganic fertiliser requirements. Klassen et al. (2006) conclude that the velvet bean should also be considered as a cover crop in the development of best management practices to protect water quality.

FAO (2014) agrees with work done by King, Mungomery and Hughes (1965) which state that a velvet bean crop can yield 17,4 tonne of green material per hectare; and that its nitrogen content of 331 kg/ha was equivalent to 1 615 kg of ammonia sulphate per hectare. FAO (2014) also refers to results which Doherty (1963) has obtained, mentioning a yield of 11 176 kg/ha of green matter from velvet beans.

The graphic illustration of Mureithi (2011) (Figure 3.1) shows that an applied 15 kg N/ha of inorganic fertiliser has increased maize yield by 38%, but when doubled the N rate leads to only an additional yield increase of 3%. Mureithi concludes that incorporated velvet bean biomass (4 t DM/ha–11 t DM/ha) as a green manure can increase plant nutrient supply and has resulted in maize yield increases of between 40%–120%.

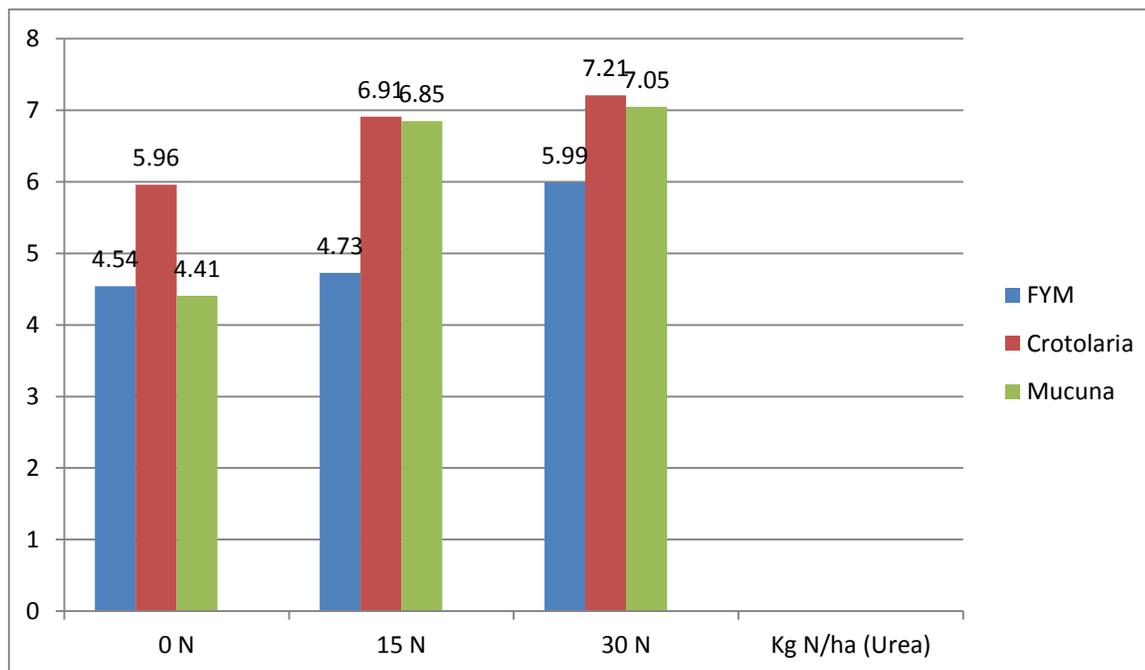


Figure 3.1 Response of maize grain yield to inorganic FYM, green manure legumes and their combination in Kakamega, western Kenya. (Source: Mureithi, 2011)

N-fixation

Lloyd (2014) claims that nitrogen is the most limiting nutrient for plant growth. The ability of a legume plant to use nitrogen from the air is a known benefit but the least understood. Lloyd (2014) states that 79% of air consists of nitrogen gas which *Rhizobium* bacteria can extract and transform into ammonia; which is then converted to ammonium nitrate and ammonium sulphate, to be used by the plant. Lloyd (2014) also declares that the nitrogen fixation process between the legume plant and rhizobia bacteria is symbiotic and the rate of nitrogen fixation is directly related to the growth rate of the legume plant.

According to Lawson et al. (2006) the velvet bean can fix high amounts of nitrogen because of its large biomass production; indicating the amount to be between 420 mg N/plant–495 mg N/plant. According to Werner and Newton (2005) seed production of the velvet bean varies from 650 kg/ha–1 300 kg/ha and is supported by biological nitrogen fixation from 87 kg/ha–171kg/ha in a season. It

is further remarked by Lloyd that the quantity of nitrogen fixed depends on soil nitrogen levels, the rhizobia strain infecting the legume, amount of legume plant growth, how the legume is managed and length of the growing season.

Capo-chichi, Weaver and Morton (2002) argue that the nitrogen-fixing and recycling ability of the velvet bean help to prevent nutrient losses, by acting as a collector or supplier of nutrients; and practically eliminates the need for costly and impractical use of external fertiliser, without compromising yield levels. Capo-chichi et al. (2002) announce that a large amount of dry matter is accumulated during the growing season, making the velvet bean a prime candidate for capturing available N.

According to Jiri (2012) velvet bean production has been successfully tested under smallholder conditions on exhausted sandy soils with biomass yields, without P applications, ranging from 2 t/ha up to 6 t/ha; noting maize yield increases of more than 64% being measured in Zimbabwe after application of velvet bean as green manure, where N contribution from velvet bean biomass ranged from 101 kg N/ha – 348 kg N/ha. Jiri (2012) further maintains that available N is largely from soil reserves and applied mineral fertilisers, stating that N might be lost as a result of leaching or as gasses through volatilisation or de-nitrification; adding that a full rate of inorganic fertiliser would supply about 120 kg N/ha. Bachman (2014) notes that it is not needed for velvet bean seed to be treated with any inoculant before planting.

Phosphorous

Ngome, Becker & Mtei (2011) mention that productivity and sustainability of agricultural production systems are determined by soil N, soil organic matter and available soil P; stating that, within permanently cropped fields, organic carbon stock and N-stock are manageable with practises such as reduced tillage and green manure. Ngome et al. (2011) also assert that cover legumes can enhance the soil P-content in the long run; indicating that P-acquisition from either fertiliser application or deep-rooting legumes will stimulate carbon accumulation and added N from fixation, all be available to the associated crop upon incorporation and organic matter mineralisation.

According to Lawson et al. (2006) the dominance of the velvet bean in nitrogen fixing ability also promotes the availability of some other soil nutrients such as phosphorous. Jiri (2012) affirms that the green-manure system of the velvet bean indicates a build-up of P-reserves, with availability to remain fairly stable in the velvet bean system. However it is mentioned that, together with higher grain yields exporting more P, some P-fixation can occur on clayey soils.

Diop (2002) reports that the Regenerative Agricultural Research Centre is working with about 2 000 American farmers in trying to improve the soil quality by adding legumes and green manures; hoping to improve the use of manures and rock phosphate, incorporate water harvesting systems and develop an effective composting system. According to Buckles, Triomphe & Sain (1998) N and P are common limiting factors in crop production, especially in systems that include a legume to supply N; shortages of P are frequently becoming a major obstacle to sustained yields, which makes the adequate supply of available P over time a critical concern in the velvet bean system.

Buckles et al. (1998) state that, from a conservative view, P availability seems to remain fairly stable in the velvet bean system despite yearly exports. Buckles et al. (1998) add that, as with other nutrients, decomposition of velvet bean biomass is also a source of available P; resulting in yearly additions of P via the above-ground biomass to reach about 15 kg P/ha–20 kg P/ha. However, according to Bachman (2014), the velvet bean plant does respond to applications of phosphate, at a rate of 112 kg/ha–225 kg/ha (Table 3.6).

- *Other nutrients*

Table 3.6 Buckles et al. listed the following nutrients other than N in the aboveground biomass of the velvet bean at four sites, northern Honduras (December, 1993).

Nutrient	Average	Minimum	Maximum
Total K (kg/ha)	100 ± 24	82	114
% of total K in litter	18 ± 9	11	27
Total Ca (kg/ha)	140 ± 37	111	159
% of total Ca in litter	70 ± 10	62	78
Total Mg (kg/ha)	26 ± 7	22	32
% of total Mg in litter	56 ± 12	45	67

(Source: Buckles et al.)

- *Weed control (suppressor)*

Table 3.7 indicates authors who have done research work on the use of the velvet bean as a weed suppressor.

Table 3.7 Research work done on the velvet bean as weed suppressor

Controls	Location	Reference
Broadleaves	Ghana	Lawson et al. (2006)
Grasses		
Sedges		
Weeds, nematodes, pests	Mexico	Caamal-Maldonado et al. (2001)
Grass	Nigeria	Olorunmaiye (2010)
Broadleaves		
Weeds	Mesoamerica	Hammerton (2002)
Broadleaves		
Weeds	Benin	Barret et al. (2002)
Weeds	Africa	Thierfelder & Wall (2013)

(Source: Author)

According to Caamal-Maldonado et al. (2001) vigorous growth of annual legumes covers the soil with a thick vegetative layer which reduces the light, preventing extreme temperature changes — thereby impairing weed growth; adding that the velvet bean also has allelopathic potential (agent known as L-dopa) that helps to control weed growth (being helophytes) and reduces other harmful pests such as nematodes and insects. According to Lawson et al. (2006) the cultivation of crops is hindered by some problems, of which weed interference is identified as most problematic; disclosing that yield losses as a result of weed competition can be as high as 55% for maize.

However Lawson et al. (2006) claim that inter-cropping could help to suppress weed at secondary growth after ground cover has been fully established; and refer to the use of velvet beans as a weed control strategy by forming a dense mat of vegetation to cut off sunlight, to smother weeds. In this, Hammerton (2002) refers to the velvet bean as a legume species of choice. It seems to be very effective in suppressing and eliminating certain severe weeds, such as nut-grass (*Cyperus rotundus*), Bermuda grass (*Cynodon dactylon*) and cogon grass (*Imperata cylindrica*).

Jiri (2012) argues that maize–velvet bean rotations have the potential to improve grain water productivity, soil fertility and to be a livestock feed; stating that farmers adopting such a technology are not mainly based on agronomic performance but also by other factors that would be important to the overall farm production and household needs. Olorunmaiye (2010) states that research has shown the velvet bean to be efficient in reducing weeding frequency and simultaneously increasing

crop yield; adding that weed and labour demand required for weed control are among the most important production constraints. Jiri (2012) also maintains that, with the current negative trend of high inorganic fertiliser costs, it is crucial to make such technologies accessible to farmers.

In this regard Lawson et al. (2006) refer to the ability of the velvet bean to decrease the prevalence of grasses and sedges by means of smothering as a cover crop; remarking that *Mucuna* species reaches 100% ground cover within 60 days–90 days after planting. They suggest that closer planting spacing would favour better and more rapid canopy formation.

Caamal-Maldonado et al. (2001) mention that the use of herbicides causes the selective growth of weeds with the result that pesticides and herbicides such as paraquat dichlorine and 2,4-D (Esteron) are used heavily. Therefore Caamal-Maldonado et al. (2001) suggest that, as an alternative, the velvet bean gives good control of spiny amaranth, smooth pigweed, field sandbar, and bitterweed. However Caamal-Maldonado et al. (2001) mention that the continuous long-term use of one legume, to reduce seed banks, can favour weed diversity although weed shifts could occur more slowly; compared to herbicide-resistant weeds which become more difficult to eliminate.

Secondary usage

Bachman (2014) also indicates the possibility of utilising velvet bean seed as a source of industrial starch; affirming results indicating that high viscose starch —suitable as a thickening agent for food products or as an adhesive in the paper and textile industries — could be obtained.

3.2.2. Forage crop

- *Nutrient value and food potential for ruminants*

Probat (2011) asserts that, as a food source, the velvet bean contains high levels of essential daily protein, carbohydrates, lipids, fibres and minerals, which are essential in our daily diets. As a diet supplement velvet bean seed can help reduce body fat, cellulite, lower cholesterol levels, can maintain blood sugar levels and can increase energy levels. According to Bachmann (2014) the velvet bean is a nutritious animal feed which is used mainly for grazing, while mature seeds are used in manufacturing compound feeds or are fed directly to the animals after being water-soaked or grounded into a meal.

Bachmann (2014) further reports that the bean can be used to feed cattle or sheep, and can only be fed to pigs if the bean constitutes less than 25% of the diet; adding that the bean is considered unsuitable for poultry although residual cake has a protein content of 15%–20%. Mugendi et al. (2014) state that the proximate and mineral content of the velvet bean compare favourably with

edible legumes; claiming that the velvet bean is rich in protein and micronutrients. Mugendi et al. (2014) note that various processing methods can be used to reduce L-dopa contents, while other anti-nutritional compounds (trypsin inhibitors, phytates and phenolics) also are reduced significantly; with residual protein levels high (27,1%) compared to commonly consumed legumes.

According to the Australian Centre for International Agricultural Research (2010) *in-situ* feeding trials have shown that velvet bean-based diets are more effective than cowpeas; stating that such trials have caused the velvet bean to be more popular owing to higher drought tolerance and better resistance to pests and diseases than other legumes. Mugendi et al. (2014) conclude that research has shown that, as a cheap alternative source of protein, the velvet bean has good potential in diets and also could be utilised to improve food security.

3.2.3. Medicinal potential

According to Hammerton (2002) the velvet bean has a history of multiple uses in agriculture and because of biologically active compounds content. The bean also has a documented history of use as a medicinal plant. As an anthelmintic, Hammerton (2002) reports that the pods have spicules that contains mucunain which is an active pruritic agent, and being commercially sold as either itching power or an oral vermifuge. Furthermore Hammerton (2002) states that the velvet bean is a constituent of more than 200 indigenous drug formulations in India, indicating a heavy demand for the bean which fuelled the commercial cultivation thereof.

Tattva's Herbs (2013) lists some health benefits of the velvet bean as

- i) providing L-dopa, which turns into dopamine — improving mood, sense of well-being, mental clarity, better sleep, and brain function
- ii) produces testosterone, which increases libido in both men and women
- iii) increases energy
- iv) improving mental capacity, and
- v) promoting brain activity; combating diseases such as Parkinson's disease and depression.

- *Parkinson's disease*

Hammerton (2002) states that the velvet bean plant contains a large number of chemical compounds which have pharmacological properties — and lists among others L-dopa (3-(3,4-dihydroxyphenyl) alanine), nicotine and serotonin — and allegedly contains a number of tryptamines which have hallucinogenic properties. Alo et al. (2012) state that the endocarp of the velvet bean is nontoxic and 2 times–3 times more potent than levodopa if needed or taken for controlling the hyperprolactinemia motor symptoms of Parkinson's disease. They also declare that

the bean has exhibited a neuro-protective effect by increasing brain mitochondrial complex-I activity, by restoring dopamine and norepinephrine levels in Parkinsonism animal models.

According to Hammerton (2002) the L-dopa substance allows impulses to be sent from one nerve cell to another in the brains; remarking that with Parkinson's disease insufficient dopamine is produced. The disease includes symptoms such as trembling, stooped posture, poor balance and slowness of body movements. Martin-Kilgour (2009) adds that the L-dopa from velvet beans are safer and more effective for controlling Parkinson's disease, a deficiency of the neurotransmitter dopamine; mainly because the array of other accompanying chemical constituents in the unprocessed plant also plays a role.

Hammerton (2002) further maintains that, when the seed of the bean has been used as a treatment for more than 4 500 years in Ayurveda, trials have suggested that L-dopa is two to three times more effective than equivalent amounts of synthetic L-dopa; suggesting that either the bean contains compounds that enhance the efficacy of L-dopa, or that constituents of the bean independently reduce the symptoms. Martin-Kilgour (2009) also mentions that the velvet bean looks promising as treatment for recovering drug addicts and people suffering from depression-related illness; mentioning that depressed people have deficiencies of the neurotransmitters serotonin and dopamine. Hammerton (2002) concludes by adding that L-dopa is also known as a libido booster, and has suggested its use as an alternative to Viagra.

- *Toxicity*

Feedipedia (2013) also asserts that the toxicological problems of the velvet bean are as a result of its seeds containing 6%–7% L-dopa, from which dopamine is prepared, and dimethyltryptamine, a hallucinogenic substance. It is also said that, being less harmful in ruminants, L-dopa might cause severe vomiting and diarrhoea in pigs fed large quantities of velvet bean seed. Furthermore, the seed contains mucunaine (skin itching), prurienine and serotine alkaloids as well as anti-nutritional factors such as trypsin and chymotrypsin-inhibiting activities, high phytate content and the oligosaccharide verbascose.

Feedipedia (2013) states that these anti-nutritional factors can be reduced efficiently by a wide range of treatment processes such as boiling in water, autoclaving and ensiling. However Hammerton (2002) does mention that observation has revealed that L-dopa content varies between locations where a negative regression coefficient of L-dopa content on latitude accounted for 78% of the variation; indicating that L-dopa levels decreased with latitude.

3.3. Effect of the velvet bean on maize yields

According to Du Plessis (2003) a ton of maize grain removes 15 kg–18 kg of N, 2,5 kg–3,0 kg of P, and 3,0 kg–4,0 kg of K from the soil; adding that 10 kg–16 kg of grain is produced for every millimetre of water used, saying that a 3,1 t/ha yield will require between 350 mm and 450 mm of rain per annum. Important to note is what Adriaanse (2013) maintains about inorganic N soil levels, which should be managed between 70 kg/ha and 133 kg/ha for biological and economic reasons; not exceeding 174 kg/ha because of possible yield depressions occurring as much as 10% above the latter level.

Du Plessis (2003) also notes the importance that 1 t/ha of maize yield delivers 1 t of plant residue, which can cover 10% of the soil. For conservation tillage to conserve moisture a minimum yield of 3 t/ha is needed to obtain a 30% surface cover, whereas the aim should be 50%–60% to be effective. Lawson et al. (2006) indicate that increases in maize biomass production are attributed mainly to nitrogen transfer from legumes to maize; stating that weed suppression by cover crops also contributed and remarking that velvet bean–maize intercropping gave higher yields at wider spacing because of more space for spreading to increase smothering effect on weeds.

Werner and Newton (2005) maintain that the velvet bean used as green manure and in crop rotation with maize has increased yields by 50%–100%, compared to non-fertilised control plots; confirming these data in Mexico, using the system maize–velvet bean–maize. According to Carsky (2002) the cropping benefit of the velvet bean to farmers in the form of higher maize yields was 3 t/ha–4 t/ha, without any additional applied nitrogen fertiliser (similar to obtained yields with recommended fertilisation levels of 130 kg N/ha); also asserting that the velvet bean can provide — as an intercrop — more than 100 kg N/ha to the following maize.

Over an eight-year period, Carsky (2002) calculates the benefit:cost analysis at a ratio of 1:24 when the velvet bean was included in the system; and if the seed was sold, the ratio increased to a ratio as high as 3:56. According to Okito et al. (2004) research data suggest that the long-term use of the velvet bean in sequence with maize would lead to an increase of soil N and hence organic matter. Okito et al. (2004) also affirm that the highest maize yields were obtained when planted after the velvet bean, which is renowned for accumulating and fixing high amounts of N. They add that the velvet bean–maize sequence would lead to a build-up of soil nitrogen. Hammerton (2002) indicates that the velvet bean, when incorporated into the soil, can often approximately double subsequent crop yields and as a mulch, it increased yields by about 35%; adding that even dry beans following the velvet bean showed yield increases of over 100%.

Carsky (2002) concludes by commenting that, based on a yearly cost-ratio analysis, a declining trend was observed which suggests that additional external fertiliser inputs (P and K) are required to achieve sustainable production. Adoption of the velvet bean technique would save the Mono Province (Costa Rica) about 6,5 million kg of nitrogen or about \$US 1,85 million/year.

3.4. SWOT analysis of the velvet bean

3.4.1. Introduction

Goodrich (2013) reports that a SWOT analysis, used in conjunction with other analysis tools, is an assessment technique as a precursor to any sort of business action, helping to develop a full awareness of all factors that may affect strategic planning and decision-making. Goodrich (2013) also declares that Strengths and Weaknesses refer to internal factors, meaning the resources and experience readily available such as financial, physical and human resources, as well as current processes. Rouse (2013) remarks that, once the SWOT elements are identified, the decision-maker should be able better to ascertain if the product or goal is worth pursuing and what is required to make it successful. Furthermore Goodrich (2013) maintains that all businesses are influenced and are affected by external forces, whether it is direct or indirect to an opportunity or threat — typically factors the business does not control such as market and economic trends, funding and demographics.

- *Strengths*

The *Miriam-Webster Dictionary* (2014) defines strength as a strong attribute or inherent asset which has a powerful endurance capacity to resist a force or an attack. Berry (2014) defines strengths as internal, positive attributes which can be tangible and intangible and which are within your control. Morrison (2014) asserts that strengths are those qualities that are good, and advises that you maintain and build on them; to be used as competitive leverage.

- *Weaknesses*

Roos and Talmon (2014) refer to weaknesses as qualities that hamper the agricultural business from achieving its objectives or full potential — reasons being insufficient research and development, a depreciating set of machinery and poor decision-making. Roos and Talmon (2014) also mention that possible weaknesses such as employee turnover and huge debts can be controlled, minimised or eliminated.

- *Opportunities*

For-Learn (2007) affirms that it is useful for a business to consider strengths that can open up opportunities which can be used for scenario building; such as changes in technology and markets, government policies and social patterns or lifestyles. QuickMBA (2010c) declares that, as an external environmental analysis, an opportunity offers the chance to introduce a new product; which in turn can generate superior returns in new business possibilities.

- *Threats*

BusinessDictionary (2014) defines a threat as a negative event that runs the risk to become a loss, and the likelihood of the occurrence of the event — being a natural phenomenon such as an earthquake, a flood, or a man-made incident such as fire. Friesner (2014) refers to a threat as a negative external factor in business. NetMBA (2010) states that existing product changes might be perceived in the market as a threat; necessitating product specifications to change or for new product development to remain competitive. In Table 3.8 the elements of a SWOT analysis are applied to the velvet bean.

Table 3.8 SWOT analysis of the velvet bean in table format

<u>Strengths</u>	<u>Weaknesses</u>
<ul style="list-style-type: none"> • Fast grower and good drought tolerance • Zero risk to soil health • Seed are easy to produce • Increases soil biodiversity of beneficial microbes by stimulating their growth • Ease of establishment — large seed does not need completed land preparation and cover the soil quickly • Improves soil fertility and fixes atmospheric nitrogen • As cover crop — shows substantial weed suppression potential • Is grown separate as a green manure, a cover crop, or mixed with other crops; making it a valuable anti-erosion crop • Resistance to pests and diseases • High potential to rehabilitate weed-infested land (<i>Imperata cylindrica</i>) • High digestibility, crude protein and mineral content — rich in protein and micro-nutrients • Can be used to make high-quality hay and concentrated feed — the leaves and vines make excellent fodder • Does have secondary capabilities as a high viscose starch • Contains high volume of unsaturated fats in the seed • Shows good traits of drought resistance while also moderate resistant to cold • One of the best food sources of the amino acid L-dopa, a direct precursor to the hormone dopamine • Through raising low dopamine levels, <i>Mucuna pruriens</i> can have a positive effect on motivation, attention, mood, relaxation, libido, sleep and many other areas • Mucuna extract helps reduce excessive prolactin and increases testosterone in the body. Many women and men notice an increase in sexual desire and performance when taking the herb owing to higher testosterone levels • Raising dopamine with velvet beans also helps stimulate human growth hormone production for enhanced muscle growth, fat burning and anti-aging effects 	<ul style="list-style-type: none"> • Presence of L-dopa and other toxic and anti-nutritive compounds in seed — making monogastric uses problematic • Low content of sulphur amino acids reduces nutritional value • Low palatability of foliage • Has a longer growth period, and are more difficult to thresh • Limited drought tolerance at young age • Lacks adaptation to very acid, low fertile soils • Large amounts of green manures are needed • Cultivation can be labour intensive • The nutrients only become available after the decomposition process, which may mean a wait of 2 months–3 months • It is reported that the velvet bean can strengthen <i>Rottboellia</i> populations • Oil production – low levels of seed oil content can preclude the velvet bean as oilcake source

Table 3.8 SWOT analysis of the velvet bean in table format (continued)

<u>Opportunities</u>	<u>Threats</u>
<ul style="list-style-type: none"> • Oil production — can play a role in national self-reliance in edible oils • Can contribute to earning foreign exchange • On-farm nitrogen fixation and contributes to natural capital • Rural employment through agro-industry • Compatibility as intercrop with other crops such as maize, wheat and sorghum • Monetary returns for farmers • Rehabilitation of degraded lands through crop rotation • Contribute to soil fertility through organic matter addition — 4 t/ha–11 t/ha of DM and 87 kg N/ha–171 kg N/ha of fixed nitrogen • Seed saved from previous harvest —farmers not dependent on external seed delivery • Green manure is cheap, organic and readily available • Velvet bean has the potential to suppress soil borne fungal diseases • Velvet bean can be used as green manure to reclaim saline and acidic soils 	<ul style="list-style-type: none"> • Toxicological problems of velvet bean are owing to its seeds • May not be used as the sole protein in the human diet • Uncontrolled — velvet beans can cause problems as an intercrop, such as competition and entanglement of the main crop • Lack of research on velvet bean as a cash crop • Poor availability of good quality velvet bean seed • Competition from soybean and lupine • Lack of commercial seed market

(Source: Author)

3.5. Competitive environment according to Porter's five forces

Ehmke et al. (2004) state that the complexity of the economic structure of an industry is the result of long-term social trends and economic forces; being faced with increased regulations and public opinions, businesses nowadays are more accountable for their impact on society. Ehmke et al. further claim that, for a business manager, the economic structure determines the competitive rules and strategies to be used. Seeing that external forces which affect profitability are beyond control; management must choose tactics in response to the forces rather than try to change the business environment. Deshpande (2008) has the viewpoint that necessity is the mother of all inventions and that it is now the time for intelligent people to think about inventing; therefore, Deshpande (2008) sees the Porter model as the first step towards a multilateral intervention within the agricultural sector.

Ehmke et al. (2004) feel that this forces concept, most often applied to industries producing and marketing differentiated products, provides the entrepreneur with a tool to examine the profit potential of an industry by countering the strength of forces. ReportLinker (2014) indicates that,

owing to the rise in the global population, agriculture will experience increased production pressure to meet higher food demand. Although agricultural production is expected to grow in the next few years it is considered that commodity prices are to decline. Deshpande (2008) argues that farmers have been cocooned within their village economies and consequently have a lot of re-thinking scope about how money can be diverted towards development spaces; stating that by determining the impact of the exposed external forces on an industry, the business dynamics can be altered to being more favourable to the farmer.

Adding to this ReportLinker (2014) indicates that a general rise in production costs of a crop will see lower outputs; therefore, important developments in fertilisers, chemicals and seeds will be the key in helping the sector rise to the challenge of supplying affordable and abundance of basic plant- and animal-based nutrients. Ehmke et al. (2004) see strong forces associated with more challenges, therefore the strength of the five forces will determine ultimately the profit potential of a business by influencing the product price, costs and required investments of the businesses.

3.5.1. Porter's generic strategies and competitive advantage

Agricultural Marketing Resource Center (2014) defines competitive advantage as those characteristics which a business does better than its competitors and can be derived from a variety of sources. It may involve special skills or resources possessed, or by lowering production costs. Hammer (2004) declares that competitive advantage can be yielded through innovation in operations, such as developing new products or by undertaking any other new activities; adding that innovation mostly started as a grass-root movement that is committed to finding and exploiting new opportunities.

According to Ekpott (2012) Africa offers many diverse opportunities and is a logical place for pursuing agricultural ventures, because of such reasons as that agriculture is ingrained into the culture, that the continent can meet diverse requirements and that the potential local market has outstripped production; commenting that challenges such as yields, inputs and infrastructure can be addressed with systematic interventions.

Hammer (2014) mentions the importance for the business to set performance goals which will stimulate radical thinking and willingness to overturn tradition; by reassessing the critical dimensions of work, the manager should consider adjusting working dimensions to create a new operational design that delivers better performance. Ekpott (2012) also draws attention to the strategic importance of a business developing ventures to meet local consumption, by offering markets for food products. Ehmke (2008) claims that a competitive advantage can mean increased

profit and a business that is sustainable and successful over the long term to a grower and/or producer.

Ehmke (2008) adds that a producer who is familiar with farming knows that successful agriculture has operated typically in a commoditised, price-driven market, where the same product is produced; implying that the ultimate winner is the most cost-efficient producer — meaning focused strategies on lowering cost and higher volumes. However, Ehmke (2008) notes that strategies do not only focus on costs and volumes exclusively, but rather that the product or service may be of premium quality; in other words, also being differentiated (such as organic, natural, or humane production), or having a value-added component (focus or niche).

According to Oxford Learning Lab (2012), to achieve a sustainable competitive advantage, a business should consider its competitive advantage within the context of

- i) the sources of competitive advantage which establish either a differentiated product or being the lowest cost producer in the industry, and
- ii) that the competitive scope of the market determines its focus.

The Economic Times (2014) indicates that there are three generic strategies developed by Porter, namely cost leadership, differentiation, and focus; which can be used as a strategy by business to gain competitive advantage; as shown in Figure 3.2.

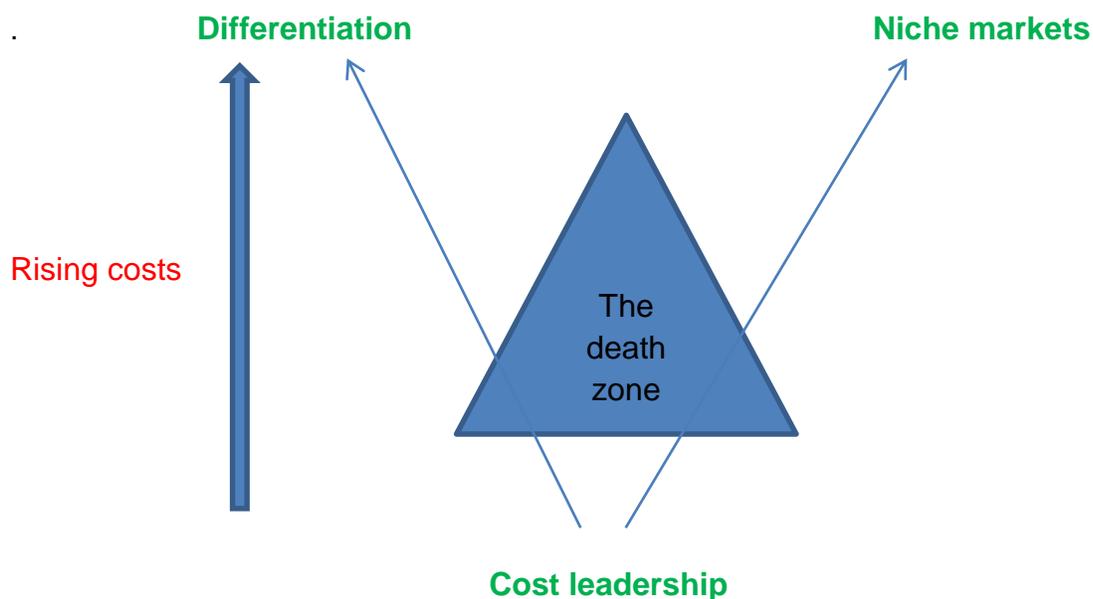


Figure 3.2 The three generic strategies

(Source: Oxford Learning Lab)

- *Cost leadership*

Oxford Learning Lab (2012) states that a cost leader in any market gains competitive advantage if able to produce products at the lowest cost; ways to obtain these low costs include unique access to low-cost material sources, efficiency and effectiveness, and avoiding supplementary costs with the aim to sell a standard and no-frills product. Tanwar (2013) reports that — should a business wants to maintain this strategy — it should continually search for cost reductions in all aspects of the business. To be successful will require a considerable market share advantage or benefits such as sustained access to inexpensive capital, tight cost control and incentives based on quantitative targets.

- *Differentiation*

Allison (2013) states that — with a differentiation strategy — the business seeks for product uniqueness within the industry for which customers will pay a premium price, leading to profitability; also claiming that differentiation creates a perception of exclusivity which is incompatible with higher market share. The focus instead should be on customer loyalty. According to Vargas Sanchez (2010) a business should consider three essential tests when considering whether to diversify. These are the attractive test, the cost-of-entry test, and the better-off test; also noting the potential advantages of this strategy as being economies of scope (cost savings by using a resource in multiple activities in combination) and that of internal market (for capital and employees).

- *Focus or niche*

Friesner (2014) writes that — with a focus strategy — the business focuses its effort and resources on a narrow, defined market segment in creating competitive advantage; but warns that small and specialist niches could disappear in the long term, an unachievable strategy with an industry that depends on economies of scale. QuickMBA (2010b) remarks that a business that focuses on this strategy should bring something new into the market mix, such as having increasingly specialised products, or increase differentiation through innovation and knowledge of the needs of the target customers; but, such businesses face risks which include imitation and changes in the target segments.

Oxford Learning Lab (2012) mentions that, according to Porter, long-term success can only be achieved if the business selects one of these generic strategies; trying all can create a confusing image which will leave the business stuck in the middle without creating any true competitive advantage and with almost guaranteed low profitability.

3.6. PEST analysis

Chamarti (2011) states that PEST is a strategic framework used to scan the external micro-environment in which a business operates; playing an important role in value-creation opportunities of a strategy. According to Khan (2011) these macro-environmental factors may be indicative of new potentials and opportunities; describing the acronym as **P**olitical analysis (intervention, environmental laws, risk of political instability), **E**conomic analysis (imports, economic growth, government spending, income levels, job growth), **S**ocial analysis (lifestyles, employment patterns, population growth, cultural aspects, career attitudes), and **T**echnological analysis (R&D, rate of technological change, technological impact).

Chamarti (2011) mentions that these factors are usually beyond the control of the business and must be considered as either threats or opportunities; also saying that macro-economic factors can differ per continent, country or even region.

3.6.1. Political

On the one hand, one can argue about the newly published regulative restrictions hindering the potential commercial development of the medicinal market for velvet beans. With reference to Doms (2014) who maintains that the government has launched a plan to clean up the complementary medicine industry in South Africa with the aim to protect public safety; and who refers to Regulation 48C 2(d)(ii) published on 15 November 2013, Kahn (2014) notes two points:

- i) no new complementary and unregistered medicine may be marketed, and
- ii) the product must comply with the regulatory definition of complementary medicine;

adding that, when implemented, the nature and characteristic of the industry will change dramatically. Doms (2014) states that when the Medical Control Council determines registration as a Category A or D medicine, the safety, quality and therapeutic efficacy's merits of the medicine in relation to its health effect is considered; noting that Category D complementary medicine means any mixture of substances that

- originates from plants, minerals or animals;
- is used in assisting the innate healing power of humans to mitigate, to modify, to alleviate or to prevent illnesses or their symptoms or abnormal physical or mental state; and
- is used in accordance with the practice of the professions of, amongst other, Ayurveda.

Doms (2014) does not argue the clarity about labelling disclaimers that proclaims about unregistered complementary medicine which may neither diagnose, treat, cure or prevent any

disease nor may it affect any physical, mental or physiological function; as the latter is excluded from the definition of complementary medicine. Kahn (2014) expresses concern that compliance with the new labelling regulations likely will be too costly for some suppliers, forcing them to close and pushing prices up to a non-viable extent. Kahn also shares concern about the effect of new regulations on the viability and sustainability of other players, and fear many job losses.

Conversely, one can argue that renewed velvet bean production can possibly slot into the goals of the National Development Plan (NDP) for 2030. According to South Africa Government Online (2014) the NDP is aimed at eliminating poverty and reducing inequality by 2030, by developing an inclusive economy, building capabilities, and working together to solve complex problems. An enabling milestone for the Government is to realise a food trade surplus, with a third being produced by small-scale farmers through the social actions of reducing poverty and inequality, raising employment and investment; as well as a strategy to raise rural incomes and interventions to ensure environmental sustainability and resilience to famine.

The aim of the Government is to create elements of a decent living standard through income generation and the social security of adequate nutrition. The *George Herald* (2012) discloses that for 2030 the NDP focuses on agricultural development as the primary economic activity in rural areas — based on successful land reform, employment creation and strong environmental safeguards. According to the *George Herald* (2012) the NDP emphasises that the grain, oilseed and livestock industries are seen as strategic; given their role in food security and as animal feed supplier, with legumes showing potential for expansion in the food chain while maize has room for expansion, given the increased animal feed demand.

3.6.2. Economic (C-B analysis)

According to Rodriguez-Kabana (1997) the velvet bean was held in high esteem until the 1950s when, after World War II, cheaper nitrogen fertiliser and mechanisation development allowed for soya beans to become the glamour crop; promising greater economic and nutritional benefits as cash crop and feedstuff. Referring to economic benefits Buckles, Triomphe and Sai (1998) indicate that the velvet bean can be utilised successfully for its fertiliser effect, easing out land preparations, advantages of weed and nematode control in subsequent crops, moisture conservation by its mulch and controlling erosion.

According to Kaizzi, Ssali & Vlek (2006), to determine the benefits of alternative cost-effective strategies in meeting the N requirement of crops, it is important for a farmer to understand the fertiliser requirements of different soils and cropping systems. Rodriguez-Kabana (1997) explores the effectiveness of the bean as the only plant that can deal with a wide range of controlling

nematodes, suppressing weeds, diseases and insects, having potential as a cash crop, and help to meet livestock feeding needs; meaning that the bean can be viewed as an organic, sustainable pesticide and commoditised crop.

Kaizzi et al. (2006) refer to the cost ratio (C/B) which is used as an indicator of the profitability of a given practice; mentioning that a C/B value of one is the break-even point for farmers, with a ratio below one implying that the cost is not recovered and with such yields easily can fall into a spiral of increasing poverty.

3.6.3. Social

Haider (2012) indicates that the velvet bean grows everywhere and that it is found in many performance-enhancing supplements; mentioning that the bean contains muscle growth amino acids, growth hormones, being an androgenic herb, and contains elements for increasing muscle tone. Owing to raising low L-dopa levels, Dillan (2014) states that the velvet bean has other benefits such as having a positive effect on motivation, attention, mood, relaxation, libido and sleep; also reducing excessive prolactin and increasing testosterone, as well as stimulating fat burning and displaying anti-aging effects. Haider (2012) stresses that, owing to the L-dopa production, the bean can also be used for treating drug addiction; apart from helping with concentration and building bone density.

Rodriquez-Kabana (1997) asserts that, because the velvet bean contains L-Dopa, additional markets might open up. However, although it sounds promising there are obstacles to overcome, such as convincing farmers that the bean is worthwhile as a rotational crop, seed availability, and development which enable varieties that mature in 90 days–100 days from planting.

3.6.4. Technology

According to Wilk (1995) sustainable technological development should have the goal to combine the strengths of modern and traditional technologies; adding that experience has shown that the main obstacles to technological development are not technical, but rather social and economic. Christina (2013) declares that innovation in the energy spaces have potential to have an impact on the farm, allowing entrepreneurs to take advantage of new technologies. When deployed effectively it will work towards achieving long-term objectives such as efficient farm management as well as resource efficiency.

Wilk (1995) argues that

- i) technology is dynamic and is sustained through constant innovation and experimentation,

- ii) efforts that transfer technology should not ignore local circumstances, local technologies, and local systems of knowledge, and
- iii) sustainable technologies can emerge as accidental or intentional hybrids that incorporates traditional and scientific technologies through collaboration.

Therefore, Christina (2013) claims that a farmer should look for technological offerings that can

- i) increase profitability, productivity and efficiency;
- ii) improve the livelihood of the farmer, the animal and the consumer with better work environments, food safety and food security, and
- iii) protect the planet and its finite resources.

Wilk (1995) remarks that, while farmers have made their own innovations, researchers have discovered green cropping as a sustainable technology, as part of alley-cropping and reduced-tillage systems. Wilk (1995) concludes by referring to the velvet bean as a technology by asserting that it has been proved useful as a crop, crowding out weeds, managing a number of pests and improving soil fertility without the use of chemical fertilisers.

3.7. Summary

This chapter agrees with Buckles (1995) that the story of the velvet bean has shown that agricultural innovation is neither static nor the purview of a few privileged innovators. This study suggests that sustainable cropping systems can be promoted as dynamic systems responsive to changing production conditions and the environment of a farmer. For the farmer, technological changes can be seen as either a threat or an opportunity and he should develop a strategic plan to use them to his advantage.

In South Africa many crops are grown on land with poor soil structure, with inadequate soil fertility management and erratic rainfall; which means that land productivity is low and variable. However, these constraints can be overcome by the rational exploitation of the resource base and minimising the need for purchased inputs. Farmers adopting the velvet bean as a technology can benefit from three advantages, namely

- i) higher land productivity,
- ii) obtaining a larger cash income, and
- iii) better resistance to droughts.

Whilst the properties of the velvet bean technique still are relatively unknown, further evaluation by farmers and attempts to improve and to disseminate the velvet bean should be considered;

applying modern criteria and methods to evaluate comparatively the input cost benefits provided by the velvet bean. This chapter also shows that a multi-disciplinary collaboration is required to reach an appropriate crop management style in biotic resources of agro-ecosystems. However, some basic behavioural requirements are needed for adopting its technical message; such as self-reliance, appreciation of the resource base, learning and teaching by doing and spontaneous spreading of technology amongst farmers.

As from the above, it is clear that the use of the velvet bean as a cover crop concept in South African agriculture should be considered by commodity and legume farmers, not only as a rudimentary way but in a broader sense to add nitrogen to their soil.

The next chapter will take the reader through a series of calculations which prove and emphasise the economic contributions of the velvet bean as far as nitrogen value is concerned.

'Life is risky. We cannot remember the future.' Anderson and Dillon (1992)

CHAPTER 4: COMPETITIVE ADVANTAGE OF THE VELVET BEAN

As the preceding chapters have informed the reader about the literature rational for cultivating the velvet bean, this chapter consists of a series of calculations which indicates the financial contribution and the currency value of available nitrogen in the soil, as fixed by the velvet bean.

4.1. Study background

According to Mangwiro, Dhliwayo and Nyamushamba (2013) the core theory of sustainable farming lies therein that the farmer is not solely dependent on a single source of energy; diversifying the farming system as such to enable financial, social and environmental stability. The purpose of this study is vested in the problems as indicated in Chapter 1; with the overall objective to analyse the impact of the velvet bean on the competitive environment in the South African agricultural sector.

Mangwiro et al. (2013) refer to the most expensive animal feed ingredient as being protein, which is obtained from soya beans, remarking that stiff competition exists between humans and animals for this protein; emphasising the need to identify alternative and cheaper sources of protein, and mentioned the velvet bean as a possibility. In the preceding chapters, the competitive environment has been discussed and important decision-making factors for a producer have been stressed; also the usages of the velvet bean have been discussed with the advantages of its cultivation being highlighted.

This chapter addresses the objectives of the study as stated in Chapter 1.6, and provides a summary and conclusions regarding the findings; giving rise to certain recommendations for future research as well as presenting a discussion of the limitations.

4.2. Research method

The research method explains how the study was done, and the discussion starts with the type of research and the objectives of the literature study. This is followed by a description of the competitive calculations done which will draw attention to the potential benefits of producing the velvet bean, if compared with two other legumes. De Kock (2008:4) refers to Sekaran who states that research can be undertaken for two different purposes, namely;

- Applied research — done with the intention of applying the results obtained to solve specific problems currently experienced in an industry, and
- Basic or fundamental research — done to enhance the understanding of certain problems that commonly occurs in an industry and to search for methods of solving them.

The research type utilised in this study is basic or fundamental research, applied as a case study.

4.3. Evaluating the main economic contributions of the velvet bean

4.3.1. Fertiliser prices

As previously stated, the velvet bean is a legume with the ability to fix nitrogen from the air; this inorganic nitrogen is available to subsequent crops. In determining the competitive advantage of the velvet bean, various calculations had to be done in determining the currency value of this inorganic fixed nitrogen. Getting to an average currency value of nitrogen in R/kg, the author used two values in determining an average price for nitrogen which will be used in all calculations.

Grain SA (2014) has issued these international and national fertiliser prices (Table 4.1) which will be used with those listed prices provided by Obaro (2014) in determining an average value of the specific fertiliser; as displayed with the following calculations.

Table 4.1 Fertiliser prices

Location price	Fertiliser	April 2014	% Δ in price (year to year)
International (\$/ton)	Urea (46) Eastern Europe	346	-16,6%
International (R/ton)	Urea (46) Eastern Europe	3736	-1,9%
Local (R/ton)	Urea (46)	6834	5,9%
Exchange rate (R/\$)		10,79	17,6%

(Source: Author)

Calculation: Δ in international price vs. local price = R3 098/ton (2014)

N price (R6 834 / 46% / 1 000) = R14,86/kg

N price = R19/kg (Obaro, 2014)

Average N price = R16,93/kg

From the a foregoing calculations, the reader can see that the listed local price for nitrogen (Grain SA, 2014) is R14,86/kg while Obaro (2014) lists a price of R19/kg. Ultimately an average N product price of R16,93/kg is achieved which will form the basis of the currency value in calculations.

4.3.2. Nitrogen budget

As part of production cost planning, a farmer should evaluate and consider whether any residual fertiliser is still available from the preceding crop. If it appears to be, the farmer can — by means of calculations — determine a possible reduction in fertiliser application rates, to reduce input costs without reducing yields. In Table 4.2 the reader can see that the velvet bean contributes to various levels of N fixing. An average calculation shows that the value amounts to 98 kg of fixed N/ha.

Table 4.2 Nitrogen contribution of the velvet bean as a crop

Author	Location	Kg N/ha
Werner and Newton (2005)	Americas	87–171
Jiri (2012)	Zimbabwe	120
Creamer and Baldwin (1999)	America	32*
Okito et al. (2004)	Brazil	84,8
McGrath (2001)	Honduras	150
Carlo Acosta (2009)	Puerto Rico	69
Average contribution	–	98 kg N/ha

(Source: Author)

*Creamer and Baldwin (1999) report germination problems experienced with velvet bean, resulting in lower population density of plants

A simple calculation shows that the currency value of this fixed N by the velvet bean (98 kg N/ha x R16,93/kg) amounts to R1 659,14/ha; which is a potential N cash-flow cost saving benefit to the farmer. By using information from PULA IMVULA (2011), a similar calculation can be done to determine soybean contribution (45 kg N/ha x R16,93/kg) which amounts to R761,85/ha. From these calculations the reader can see that, as a crop, the velvet bean offers a net benefit of R897,29/ha (R1 659,14–R761,85) in applied nitrogen savings to the farmer; more than double the benefit from soybeans.

4.3.3. As green manure or cover crop

Apart from being utilised as a crop, the velvet bean also shows high potential as a green or cover crop; although this is not implemented on a large scale by local producers. The fixed N within the velvet bean leaves becomes available to subsequent crops and the value thereof can also be calculated. Mureithi (2011) calculates the amount of N, which a cover crop will add to soil as follows, legume yield is given in t/DM, and N-content in leaves is given in %;

- As an example: *Mucuna pruriens*

Biomass yield 7 t DM/ha within six months

N content In leaves between 2,5%–5,4%

then

7 tonnes = 7 000 kg @ about $(2,5 + 5,4) / 2 = 276,5$ kg N/ha if the whole crop is incorporated into the soil. Most crops need about 100 kg of N to grow well.

The following table (Table 4.3) displays comparative values of the authors' calculation of the N contribution of the velvet bean as green manure or cover crops.

Table 4.3 Nitrogen contribution as green manure

Author	Location	Kg N/ha
Mureithi (2011)		276
FAO (2014); Doherty, (1963)	Americas	213
FAO (2014); King, Mungomery and Hughes (1965)	Americas	331
Berry and Rhodes (2006)	South Africa	138
Sikombe (2009)	Zambia	474
Average contribution	—	286,4

(Source: Author)

Once again a farmer can determine the value, as a cost saver, of the fixed N of the velvet bean available to the subsequent crop. Two approaches can be followed: firstly, as a cash-flow influence, the average of 286,4 kg N x R16,93/kg = R4 848,75/ha. This is equal to 709 kg of urea valued at the listed local price of R6 834 (Table 4.1). Secondly, the farmer can argue that the potential benefit of fixed N can increase maize yields to the following extent — according to Mureithi (2011)

— the first 15 kg N/ha will increase maize yield by 38% and by 3% for each additional 15 kg N/ha thereafter.

Therefore, a calculation of the average amount of 286,4 kg N/ha fixed as green manure or cover crop and its effect on increased maize yields will be as follows: $((286,4 \text{ kg N/ha} - 15 \text{ kg/ha}) / 15 \text{ kg/ha}) \times 3\% = 92,3\%$. If the reader takes into consideration that the national average for maize yield is at 5,21 t/ha (Grain SA, 2014:Table 4.7.), then this increase of 92,3% in yield amounts to the value of 4,8 t/ha $(5,21 \text{ t/ha} \times 92,3\%)$; which is almost equal to the national average without any additional N fertiliser being applied. Using the velvet bean as a green manure or cover crop can lead to huge savings in imported urea, both as a cost to the farmer and to the country in the form of contributing to a positive trade balance.

4.3.4. Phosphorous budget

Literature also states that the velvet bean absorb phosphorous in the soil, and when the biomass is incorporated, Buckles et al. (1998) indicate (Table 4.4) that the decomposed biomass can make available about 15 kg–20 kg of P/ha to the subsequent crop. Literature further indicates that this decomposed biomass can also help during the transformation of rock phosphates into soluble and absorbable forms of plant phosphates. In Table 4.4 the reader can also see the listed price of Foskor for pure phosphate products.

Table 4.4 Foskor (2014) listed prices for fertiliser products and Buckles et al. (1998) calculation

Mono-ammonium phosphate (MAP) per ton	R5 177,40
Di-ammonium phosphate (DAP) per ton	R6 001,40
Author	Kg P/ha
Buckles et al.(1998)	15–20
Average contribution	17,5

(Source: Author)

However, Obaro (2014) listed the average price for P as R21/kg. If a farmer calculates the potential P savings benefit from velvet bean biomass incorporated into the soil, an additional cash-flow savings of R367,5/ha $(17,5 \text{ kg P/ha} \times \text{R}21/\text{kg})$ can be achieved. If compared to calculations in Table 4.7, the reader can see that this amount of P is more than double the amount of fertiliser needed for producing a dry bean yield of 1,5 t/ha, the national average. In the case of maize, a yield of 4.5 t/ha

requires an fertiliser application of 20 P/ha, which is almost equivalent to the calculated benefit gained from the velvet bean namely R 367,5/ha.

4.3.5. Values of velvet bean seed

The velvet bean can also be produced as a cash crop and previous literature indicates a yield of about 1,6 t/ha can be achieved. These seeds have a potential gross income cash value for the farmer, either as seed itself or as a feed. As a feed; according to Rodriquez-Kabana (1997), statistics listed that the velvet bean could sell at farm gate for 50%–60% of oilseed meal prices; which suggests that the current value of the velvet bean as a high-protein feed could be worth R3 383/ton (R3 075–R3 690/2) or R5 412/ha at an oilseed price of R6 150/ton (Grain SA, 2014; Table 4.6).

As seed; Botha (2014) gives the value of velvet bean seed as R15/kg, equal to R15 000/ton or R24 000/ha; whereas Fourie (2014) argues the medicinal value of velvet bean seed as R65/250g, equal to R260 000/ton or R39 000/ha — if processed to be used for treatment of Parkinson's disease.

4.3.6. Chemical measures

This calculation is done to show to the reader that the velvet bean also has a monetary value, a positive cash-flow implication, as far as weed control is concerned. Greef (2014) argues that several pre-emergence herbicides have been identified for weed clearing in sole and multiple cropping, and refers to two basic approaches when choosing a herbicide programme, namely; only a broad-spectrum or a broad-spectrum combined with grass control, as displayed in Table 4.5.

Table 4.5 Summary of herbicide costs for three commodities

Commodity	Broad-spectrum + grasses (R/ha)	Broad-spectrum (R/ha)
Soybeans	412	328
Dry beans	243	88
Velvet beans	155	88

(Source: Author)

With reference to Kohli et al. (2008) the velvet bean has the benefit of suppressing grasses, which has the advantage of allowing a farmer to save on herbicide expenses for chemical control over post-emerging grasses. If compared to soybeans, an input cost saving of R257/ha (R412–R155)

favours the velvet bean if no herbicide is used for controlling post-emerging grasses; compared to dry beans the saving amounts to R88/ha. These savings once again amount to lower costs and lowering risks for the farmer — the velvet bean contributing to positive cash flow as far as expenses are concerned.

4.3.7. Increase in cash-flows owing to higher yields

At this point it is important that the reader should acquaint him- or herself with the producer prices which a farmer can get for products. Being a price taker, prices are determined as per daily trading on SAFEX. Grain SA (2014) has issued the following producer prices for producers of soybean and yellow maize in the country (Table 4.6) which are used in the following calculations.

Table 4.6 Derived commodity prices

Date	Product	Price (R/ton)
22 August 2014	SAFEX — soybeans	5 300
	Argentine soya bean import parity	6 350
	Full-fat oilcake	6 150
	SAFEX — maize	1 800

(Source: Author)

The reader should also take note of the national yield averages for commodities (Table 4.7) as listed by Grain SA (2014) for South African summer crops. These values are used in the following calculations.

Table 4.7 Average yields for summer crops.

Crop	Average yield in t/ha
Maize	5,21
Soybean	1,88
Dry bean	1,54

(Source: Author)

As stated previously, the velvet bean with its N-fixing ability can contribute to higher yields in such a way that available nitrogen enhances plant growth and yield potential. A farmer can also calculate the net effect of the nitrogen of the velvet bean contributed to higher yield potential. The net spin-off of this is seen in higher cash income being reflected in cash flow.

Referring to section 4.3.2, the reader can see that the velvet bean contributes to 98 kg N/ha. Should a farmer not have the money available to invest in additional fertiliser applications, the subsequent crop can still benefit from the velvet bean and can produce high yield and income as calculated below;

- According to Mureithi's calculation (2011) the maize yield benefit is 54,6% $((98 \text{ kg N/ha} - 15 \text{ kg N/ha})/15 \text{ kg N/ha} \times 3\%)$ without additional nitrogen fertilizer applied. With a national yield average of 5,21 t/ha, a preceding crop of velvet bean can still increase maize yield to levels of 8,05 t/ha, which is likely achievable on higher-potential lands. The cash value of such a maize yield increase can amount to an additional R5 120,39/ha $(5,21 \text{ t/ha} \times 54,6\% \times \text{R1 800/t})$ or 2,84 t/ha $(5,21 \text{ t/ha} \times 54,6\%)$ owing to N contribution.
- If compared to the **soybean**, the reader can see that soybean also contributes to higher maize yields (44%). to an extent of R4 126,32/ha $(5,21 \text{ t/ha} \times 44\% \times \text{R1 800/t})$. PULA IMVULA (2011) indicates total N contributed as 45 kg N/ha, then; $(45 \text{ kg N/ha} - 15 \text{ kg N/ha})/15 \text{ kg N/ha}) \times 3\% = 44\%$ yield increase owing to N contribution.
- Comparing these two calculations, it becomes apparent that the velvet bean once again outperformed the soybean owing to its higher volumes of N being fixed and available to the subsequent crop. A calculation reveals the currency value of R994,07/ha $(\text{R5 120,39/ha} - \text{R4 126,32/ha})$ or 0,55 t/ha higher maize yield in favour of the velvet bean.

4.4. Cost-benefit analysis of velvet beans compared to soybeans and dry beans

4.1.1. Net profit of crop farming (R/ha unless otherwise stated)

The figures used are an adjusted means of comparative production cost budgets for production of soybean, velvet bean and dry bean. The purpose of the calculations shown (Table 4.8) is to guide the divarication actions of calculating crop budgets, break-even prices and break-even yields. All the figures can be customised for unique circumstances; without taking in consideration the benefits from utilising the velvet bean (fertiliser-, herbicide cost).

Table 4.8 Production costs: Comparative analysis for three legumes

A: GROSS INCOME				
CROPS	Soybean	A: Velvet bean at oilseed prices	B: Velvet bean at seed prices	Dry bean
Yield (t/ha)	1,8	1,5	1,5	1,5
Price (R/ton)	5 300	3 382	15 000	11 400
Marketing cost (R/ton)	105	150	105	105
Ex-Randfontein (differential) (R/ton)	280	0	0	0
Farm gate price (R/ton)	4 915	3 232	14 895	11 295
Total gross income (R/ha)	8 847	4 848	22 342,5	16 942,5
B: PRODUCTION COSTS				
DIRECT COSTS	4 623	2 241	2 241	8 926
Seed	825	300	300	2 100
Fertiliser	1 498	956	956	1 438
Herbicide	654	382	382	382
Pest control	410	308	308	308
Grain hedging	301	0	0	0
Harvest insurance	722	0	0	1 313
Casual labour	0	0	0	1 440
Packaging	0	108	108	108
Tractor spray	0	187	187	187
Insurance	215	0	0	1 650
MEGANISATION COSTS	1 250	1 189	1 189	1 189
Fuel	787	726	726	726
Repair and maintenance	463	463	463	463
Total production costs	5 873	3 430	3 430	10 115

Table 4.8 Production costs: Comparative analysis for three legumes (continued)

C: GROSS MARGIN				
Gross margin before interest	8 847	4 848	22 343	16 943
Interest	294	172	172	506
Interest on production cost	10%	For six months		
Gross margin after interest	8 553	4 677	22 171	16 437
*Calculations do not include fixed costs because of differing farming practices and strategies				
D: BREAK-EVEN ANALYSIS	Soybean	Velvet bean	Velvet bean	Dry bean
<u>1. Break-even yield (t/ha)</u>				
Farm gate price (R/ton)	4 915	3 232	14 895	11 295
Break-even yield: Production costs*	1,19	1,06	0,23	1,12
* Break-even yield (t/ha) = Total production costs farm gate price (R/ton)				
<u>2. Break-even price (R/ton)</u>				
Yield (t/ha)	1,8	1,5	1,5	1,5
Direct costs	4 623	2 241	2 241	8 926
Machinery costs	1 250	1 189	1 189	1 189
Production costs	5 873	3 430	3 430	10 115
Interest on production costs	294	172	172	506
Break-even Farm gate price (R/ton)*	3 426	2 401	2 401	7 081
add: marketing costs	105	105	105	105
Break-even contract price (R/ton)**	3 368	2 392	2 392	6 848

(Source: Author)

* Break-even farm gate price = total costs (R/ha) / budgeted yield (t/ha)

**Break-even contract price = break-even farm gate price (R/ton) + marketing costs (R/ton)

4.5. Discussion of results

4.5.1. Nitrogen contribution of the velvet bean and its value, as calculated in Table 4.8

It is important to note that economic profits measure efficiency or comparative advantage. Referring to the calculations above, this discussion shows that the velvet bean is viable as an economic commodity in the South African agricultural sector. As seen in section 4.3.1 a farmer cannot help but argue about the listed price difference between the international and local urea nitrogen fertiliser prices; amounting to an increase of R3 089/ton. The producer can only wonder what the potential profit margins of the so-called middleman might be. This also may be an indication as to why the farmer, as a price taker, experiences continued increased cost pressures on input costs.

The economic contribution of the velvet bean will be discussed under the following points:

- i) The currency value of the biologic nitrogen fixing contribution is calculated in section 4.3.2. With an average value of R16,93/kg for N, the velvet bean contributes the equivalent of R1 659,14/ha worth of pure nitrogen; of which about 60% of the N in kg will be available for the subsequent crop. In comparison, the soybean only contributes to R761,85/ha worth of nitrogen. These values give the velvet bean an advantage of more than double that of the soybean, with the result that the net gains can amount to R897,29/ha. If 60% of the produced 98 kg N/ha is available to the subsequent crop, this can mean that the total saving on nitrogen fertiliser for the whole of the country's maize producers (2 689,2 million hectares) might add to the value of R2 675,57 billion (58,8 kg x R16,93); or the value of 158 124 thousand ton of pure nitrogen fertiliser, equivalent to 343 750 ton of imported urea.
- ii) As a green manure, Mureithi (2011) has developed a formula — as shown in section 4.3.3 — to help calculating the amount of nitrogen the velvet bean can contribute to soil. By multiplying the produced dry material (in tons) by the average N content in the leaves, one can determine the total N produced by a legume as green manure. According to the comparative values of various authors, the average N produced by the velvet bean is 286,4 kg N/ha, of which 60% is available to the subsequent crop as organic nitrogen. Valued at a N price of R16,93/kg, the velvet bean produces — as a green crop — R4 848,75/ha worth of nitrogen, equal to 765 kg of urea.

This means that a possible saving of 2 million tons of imported urea to the country can be achieved, without compromising the production potential of maize. Conversely, one can argue that this amount of nitrogen fixed by the velvet bean can stimulate maize yields. Again referring to the calculations of Mureithi (2011) the potential yield increase is calculated as follows: for the first 15 kg of N applied, an increase of 38% in yield can be achieved. Thereafter, an additional yield increase

of 3% can be achieved for every 15 kg of N applied, thus with the amount of 286,4 kg/ha of N produced by the velvet bean, a total maize yield of about 4,8 t/ha can still be achieved without any additional N being applied to crops.

This yield is almost in line with the long-term average for maize which stands at 5,21 t/ha for this season. If compared to the soybean, Thonnissen et al. (2000) record that the soybean produces between 80 kg–100 kg of N/ha if incorporated as a green manure into soil. This means that, as a green manure, on average the velvet bean outperforms soybeans by providing about 318% or 196,4 kg more N/ha.

- iii) Looking at the currency value of the contribution of the velvet bean in P as calculated in section 4.3.4; according to Buckles et al. (1998) the velvet bean contributes an average of 17,5 kg P/ha as decomposed biomass. At a listed price of R21/kg P, the velvet bean contributes to R367,5/ha worth of chemical fertiliser. This means that the velvet bean can contribute to about R988 billions of savings to the maize farmers; or the equivalent value of 47 061 tons of phosphate fertiliser.
- iv) The current value of velvet bean seed can be an arbitrary issue; however, the commercial seed value amounts to R3 383/ton, as calculated by the suggestion of Rodriguez-Kabana (1997) as in section 4.3.5.

Determining the residual cake value of the velvet bean, Bachman (2014) and Mugendi et al. (2014) indicate the contribution of the velvet bean being 15%–20% and 27,1% respectively. Thus, with an average residual cake value of 22,3% the bean can contribute as residual cake to 223 kg/ton of velvet bean seed, resulting in further savings on imported cake for the country. Furthermore, although the current value of velvet bean seed is much higher than what it is calculated to be, one can argue that velvet bean seed scarcity to the farmer on the one hand and profit within the niche market of natural medicine on the other hand, can have an influence on the current market prices; resulting in a large price distortion.

Despite this price distortion, in the comparative analysis between three legumes it is shown that the velvet bean still offers good profit margins at a low commodity price. Simultaneously, one can argue that the potential of high velvet bean seed prices can be an opportunity for a farmer to gain first-mover advantage by producing and by supplying velvet bean seed to other farmers.

On the other hand, the seed price for soybeans trades higher at R5 300/ton on SAFEX, giving the commodity an advantage over the velvet bean. It is already well known to farmers and is currently not only the biggest source of animal-feed protein, but also a large source of dietary protein. With a relative low oil content of 20% (moisture-free basis — Lee et al., 2013) the soybeans account for

about 50% of total oilseed production in the world — compared to velvet bean which has a low oil content value of 8,9% (Tuleun, Carew & Patrick, 2008), which can appear to preclude the velvet bean as a commercial source of oil.

v) As stated previously, with reference to Kohli et al. (2008), the velvet bean has the benefit of suppressing grasses. This advantage allows a farmer to save on herbicide expenses for chemical control over post-emerging grasses. The calculations in section 4.3.6 show that — at a cost deficit of R257/ha — the velvet bean compares favourably to practices with soybeans where a broad-spectrum (R328/ha) together with a grass herbicide at R88/ha are used as herbicide; this at a cost of R416/ha. Such a saving also contributes to positive cash flow and lower risk to a farmer.

vi) Various calculations as in section 4.3.7 indicate that the velvet bean can contribute positively to the cash flow of a farmer; either by reducing fertiliser input cost (preceding calculations), or by increasing potential yields with the effect of gaining higher profit margins. Again using the formula of Mureithi (2011), the N legacy of the velvet bean in the soil can contribute to an 54,6% yield increase. With the average national maize yield at 5,21 t/ha, a 54,6% yield increase amounts to additional 2, 84 t/ha, equal to an extra 7,64 million tons of total maize production.

Such higher yields will have a huge impact on profitability margins of farmer in general, further supporting free cash flows. At the current SAFEX prices these surpluses can add value to the maize industry exceeding the value of R13,7 billion; extra money available to agriculture for paying its debts while government could earn more tax from the sector. These surpluses are also available for export which could add value to the current trade deficits of the country; conversely one can argue that about 1,4 million hectares of productive land could be utilised for producing and/or expanding other cash crops such as wheat and dry beans.

Compared to soybeans which only attain a 44% increase in yield, the velvet bean has higher potential to increase yields owing to higher volumes of organic N available to subsequent crops — giving the velvet bean an advantage of R994,07/ha over the soybean. These calculations show that the velvet bean can have a considerable impact on the cash flow of a farmer as well as on the micro- and macro-economy.

4.5.2. Comparative analysis between three legumes

In this discussion, as shown in section 4.4, 'dry bean' refers to sugar beans unless otherwise stated. All the cost amounts used in this calculation are obtained from Obaro (2014) and Graan SA (2014); both cost budget values which the organisations offer annually to their customers. This

discussion starts by drawing the attention of the reader to the fact that two sets of budget comparisons are conducted for the velvet bean. Firstly, the used producer price is determined by using Rodriguez-Kabana's (1997) value which amounts to R3 382/ton (hereinafter referred to as option A).

In the second comparison a seed value of R15 000/ton for the velvet bean is used as expressed by Botha (2014) (hereinafter referred to as option B). Literature states that velvet bean seed is currently selling for R20 000/ton. However, the reason for using the first two values (R 3382/ton and R 15 000/ton) is to try and achieve a conservative comparison with the velvet bean, seeing that the bean is still a new commodity and currently relative unknown in the local agricultural sector.

With regard to budgeted yield, Grain SA (2014) gives the national average yield for soybean as being 1,84 t/ha and that of dry beans as 1,54 t/ha. These values have been used as target yields in the calculations. According to Feedipedia (2013) the velvet bean can produce between 1 t/ha–2 t/ha of seed and reacts well to fertiliser application. Owing to this reaction it is decided to use 1,5 t/ha as yield target, which is in line with yields achieved with kidney beans which displays similar yield potential as the velvet bean.

- i) As far as gross income is concerned, the reader can see that option B offers by far the highest gross income/ha (R22 342,5), followed by dry beans (R16 942,5), soybeans (R8 847), and then option A (R4 848). If compared to soybeans, option B offers 2,5 times higher gross income opportunity, and towards dry beans 1,3 times higher; whereas the opportunity of option A to gross income is 1,8 times lower than soybeans and 3,49 times lower than dry beans.
- ii) Looking at production costs, the reader can see that there is a substantial difference in direct costs amongst the three legumes; with dry beans having the highest cost, followed by soybeans, and lastly the velvet bean. Meganisation costs amount to be almost equal, although soybean cost tends to be the highest. For the purpose of this comparison the focus will be on total production costs. From the calculations it can be seen that dry beans have by far the highest total production cost, namely R10 115/ha, followed by soybean with R5 873/ha, and the velvet bean with R3 430/ha. The main reason for these discrepancies lies in the cost of dry bean and soybean seed, fertiliser costs, crop insurance, and also — for dry beans — in labour and insurance.

According to these values the total production cost of the velvet bean compares more than favourably with soybeans at 58% and at 34% if compared to total production costs of dry beans. It is important to note that, in determining the cost of insurance, the value of the velvet bean could not

be established at the time. Even at the same value as dry beans the total production costs will still benefit the velvet bean.

- iii) Gross margin calculations indicate the same trend of the velvet bean proving to have the advantage. Option B displays the highest margin potential of R22 171/ha, followed by dry beans at R16 437/ha, then soybeans at R8 553/ha, and lastly option A at R4 677/ha. The gross margin potential after interest expenses of option B outperforms that of dry beans by 135% and of soybeans by 259%. The interest cost for dry beans reflects to be the highest and is 294% higher than the velvet bean.
- iv) The break-even analysis in yield (t/ha) once again shows that option B has the highest potential, probably owing to the high price of the seed which could be obtained. Interesting to note is that break even for both soybeans and dry beans are about the same, as calculated by using the farm gate prices; however from a risk point of view, from these two legumes the soybean could be the preferred crop to cultivate owing to its much lower production costs.
- v) The break-even analysis in price (R/ton) is calculated by summarising all costs, and then dividing that value by the budgeted yield/ha. The marketing costs added to the aforementioned value equal the break-even contract price for each legume. The calculations indicate that dry beans require the highest contract price per ton, followed by soybeans, with velvet beans to follow. Although option A had the lowest gross margin, such a crop activity can still have positive effects on the cash flow of a farmer. At least the cost of cultivation is recovered, but the legacy of the N fixation of the velvet bean will add economic value to the subsequent crop.

Comparing the break-even contract price of the velvet bean with the value of such seed as determined by Rodriguez-Kabana (1997), the reader can see that a gross price margin of R991/ton or R1 487/ha is still achievable. This indicates that the velvet bean can have potential for small-scale farmers or farmers with cash-flow constraints. Furthermore, the value of a break-even contract price of the velvet bean equals 45% of the SAFEX price of soybeans. It is questionable whether such seed will sell for that little. This is a question which can be answered by another study into the proposed market value for velvet beans.

4.6. Summary

The research problem was to examine the competitive environment of the velvet bean, and to determine whether the bean is suited as an economic replenishment of needed nitrogen to cash crops; also to use the bean as a business management tool for resource-poor farmers who cultivate in contrasting agro-ecological zones in the country. Throughout this chapter the reader can

see that in evaluation, the velvet bean compares superior in terms of competitive advantage compared to soya beans and dry beans.

Being a legume, the bean can be utilised as a crop, green manure or cover crop, and/or feed itself. As a crop the velvet bean contributes 98 kg N/ha or R1 659.14/ha in rand value. As a green manure or cover crop the contribution is even more significant — the velvet bean contributing to the equivalent of 4,81 t/ha of maize yield, almost equal to the national average without any additional fertiliser being applied to a crop. Even partly savings in the industry can result in huge savings for the country, contributing to positive trade balances.

The calculations show that the velvet bean is not only about N fixing, but that the bean also has contributed to available P as well as cost savings towards herbicide usage. There were no indications that subsequent yield of crops will be influenced negatively. Perhaps the biggest advantage of the velvet bean lies in the potential of achieving higher cash-flow income, either by seed sales or increased yields of subsequent crops. The cost-benefit analysis — where three legumes were compared — indicates that the velvet bean can positively contribute to lowering the risk of a farmer by reducing input costs for subsequent crops, indicating a break-even of about 71% to that of soybeans and 35% to that of dry beans.

The main benefit of the velvet bean does not only lie in direct currency value, but also indirectly by lowering mechanisation costs. In conclusion, De Villiers (2012:115) quotes from Urmson who said that, for the brave investor, a pioneering entry into Africa could provide returns that far outweigh the risks; adding that Urmson has counselled investors to "tread carefully but make an entry for sure" (2012:115). Based on the above calculations and Urmson's quote, there appears to be a solid case for farmers beginning to invest into cultivating the velvet bean as a commodity.

"Farming is a profession of hope" — Brian Brett

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

This chapter summarises the study, indicates limitations of the study, gives the reader a scope for further research into the velvet bean and concludes with recommendations about the promotion of the use of velvet beans as a commodity.

De Villiers (2012) states that resources and capabilities of a farmer are fundamental when developing a production strategy, while representing the primary sources of the business' profitability. Furthermore, De Villiers (2012) emphasised the importance of understanding the business interaction between resources, capabilities, competitive advantage and profitability; but also to understand the mechanisms through which a competitive advantage can be sustained over time, by designing strategies to exploit the above-mentioned business characteristics to their maximum potential.

5.2. Why farmers do not accept legumes

Firstly, literature shows that the main reason for producing a legume is consumption, followed by income and soil fertility. However, as shown in Table 5.1, according to literature (Kerr, Snapp, Markochirwa (deceased), Shumba & Msachi, 2007; Grossman, 2012; and Loyd, 2014) farmers do not realise the potential for adopting this technology — mainly because of a lack of knowledge.

Table 5.1 Knowledge gaps related to the velvet bean for improving soil fertility

Role	Knowledge gaps
Uses — lacking knowledge	<ul style="list-style-type: none"> • Use of legumes for human consumption and stock feed • Other uses of the velvet bean • Residual nutrient levels because of rotation and as green crop • Concept of input reduction costs
N-fixation	<ul style="list-style-type: none"> • Agro-ecological adaptation to soils and climate • Kg of N in different systems and ecologies
Crop nutrition — residue contribution	<ul style="list-style-type: none"> • Improved and synchronised nutrient release and plant uptake • N leaching and gaseous losses — measurements • Provide other organic nutrient resources — i.e. cations (Ca, Mg)
Accumulating soil organic matter	<ul style="list-style-type: none"> • Long-term build-up of soil organic matter quality • Long- and short-term benefit trade-off — organic resources • Enhanced soil organic matter benefits — water balance, soil erosion and efficient nutrient use

(Source: Author)

If the knowledge gaps of the farmer were filled, a new production system with optimal productivity and resource efficiency could be designed.

Secondly, the adoption and dissemination of legumes within a production system are nested and defined by three contextual factors, namely

- i) socio-cultural, economic, and political,
- ii) agro-ecological, and
- iii) farm management.

Thirdly,

- i) food habits which dictate the allocated land, as well as the type and amount of input invested;
- ii) fertility status of soil and indices of pests and diseases dictating the frequency of legumes within the cropping system, and
- iii) market value of crops

dictate the amount of land allocated to legumes, in such that higher-priced legumes are produced for the market while the cereals consumed are bought.

Fourthly, farmers also cite the following as setbacks: limited genetic pool of introduced germ plasma, the processing and utilisation of legumes to make market-orientated products, and — with lacking plant material — the challenge to identify high-yielding and drought-resistance species available for planting in the drought-prone South African environment.

Fifthly, the legume should not be too sensitive to unfavourable environments, while also having multiple benefits, i.e. for food, feed and soil fertility.

5.3. Summary of research

5.3.1 Chapter 1 — The research problem was to examine if the velvet bean, as a legume, has a viable economic competitive advantage within the South African agriculture. The objectives outlined in sections 1.4.1, 1.4.2 and 1.4.3 are discussed as follows.

5.3.2 Chapter 2 — Farmers make choices to improve their utility or well-being. These choices depend on economic choices about what and where crops are grown, what technologies are being used, as well as other short- and long-term management decisions taken. This chapter highlights the fact that the twentieth century brought changes in agricultural economics of developing countries. New World Trade Organisation policies have forced developing countries into open

markets, allowing for natural-resource-management approaches as possibilities into production systems.

South Africa — as an arid country — faces the challenge of climate change by dint of the enthusiasm of farmers who, embracing biotechnology, managed to deliver constant volumes of grain. This is achieved mainly by a focussed approach of synergistic and integrated management technologies which minimises external inputs; developing a sustainable agro-ecosystem round environmental, economic and social pillars. The reader is also briefed about the underlying drivers of production system changes, the role of collateral, investment-decision drivers and production decisions which are intertwined within a biophysical model, and factors that influence farmer decision-making.

It is also brought to the attention of the reader that integrated natural resource management, including conservation agriculture and technology, can lead to productivity increase which in turn can contribute to food security. The reader is further warned that agriculture is based on the notion that soil is an inexhaustible resource for continuous production increases; therefore, because soil is formed at a slow rate, it must be considered and be preserved as a non-renewable resource. Sustainable agriculture also has critical and fundamental prerequisites — such as being ecologically sound, economically viable and socially responsible. All three dimensions of sustainability are inseparable.

It is pointed out that agricultural biodiversity is declining owing to the rapid expansion of industrialisation, relatively few crop varieties cultivated within mono-cultures and globalisation of the food and marketing system.

This chapter indicates that crop production causes fertility to decline if replenishment with either organic or inorganic inputs is inadequate; recognising the strong influence of human management practices such as tillage, continuously cropping the same land and limited crop rotation. It is mentioned that the planting of legumes can assist in higher crop productivity on existing agricultural land.

The chapter concludes by taking the reader through the economics of crop diversification as well as the influence of price shifts on short-run cash income. The main focus of the latter part of the chapter is on risk, which can be mitigated by intercropping and multiple cropping; especially if grain crops can be rotated with a legume — which may be a crop in itself or be grown as a cover crop.

Based on the literature study there is a strong case for the velvet bean to be produced as a newly introduced competitive commodity in agriculture. With reference to the problem as stated in section

1.4.3; with land reform and rural development, cultivating the velvet bean can economically contribute to poverty alleviation, job creation, food security and entrepreneurship — all achieved through strict production disciplines that guarantee food security. With the velvet bean, higher opportunities of integrating segments in the value chain can be achieved with the expansion of agro-business, with the seeds as a medicinal product. With natural resource management, the bean can contribute to recovering fallow land, restricting further land degradation, de-forestation and de-certification which are all critical environmental issues. Combined with inappropriate farming methods on commercial farms a prevailing solution is the application of new agricultural technologies such as new crop varieties.

It is viewed that, with the velvet bean, sustainable agriculture should focus on the trend of soil protection, biodiversity and consumer health. With the imperative to be profitable — while being subject to the same economic pressures which affects the complex external agricultural environments worldwide — and by analysing these external environments a farmer can display the ability to earn price premiums on a commodity such as the velvet bean.

5.3.3 Chapter 3 — This chapter agrees with Buckles (1995) that the story of the velvet bean demonstrates that agricultural innovation is neither static nor the purview of a few privileged innovators. This study suggests that sustainable cropping systems can be promoted as dynamic systems responsive to changing production conditions of a farmer as well as to his environment. For the farmer, technological change can be seen as either a threat or an opportunity, and he can develop a strategic plan to use them to his advantage. In South Africa many crops are grown on land with poor soil structure, with inadequate soil fertility management and erratic rainfall; which means that land productivity is low and variable. However these constraints can be overcome by the rational exploitation of the resource base and by minimising the need for purchased inputs.

Farmers adopting the velvet bean as a technology can benefit from three advantages, namely

- i) higher land productivity,
- ii) obtaining a larger cash income, and
- iii) better resistance to droughts.

Whilst the properties of the velvet-bean technique are still relatively unknown, further evaluation by farmers and attempts to improve and to disseminate the velvet bean should be considered; by applying modern criteria and methods to evaluate comparatively the input cost benefits provided by the velvet bean.

This chapter also shows that a multi-disciplinary collaboration is required to reach an appropriate crop management style in biotic resources of agro-ecosystems. However, some basic behavioural requirements are needed for adopting its technical message; such as self-reliance, appreciation of the resource base, learning and teaching by doing, and spontaneous spreading of technology amongst farmers.

As far as the posted question in section 1.4.2 is concerned, namely 'Health considerations and Parkinson's disease'; it is brought to the attention of the reader that literature refers to sustainable agriculture as a process of protected farming techniques. Food safety should be a public health priority which requires a holistic approach from production to consumption. Consumers are at risk owing to aspects of production processes, which are exposed to a wide variety of agents within the food chain. As from the above, it is clear that the use of the velvet bean as a cover-crop concept in South African agriculture should be considered by commodity and legume farmers, not only as a rudimentary way but in a broader sense to safely add nitrogen to their soil.

The literature further states that studies have linked pesticides with the development of Parkinson's disease. A new study has found the dopamine processing gene ALDH as being susceptible to inhibition from pesticides. Researchers have also shown that, for people with certain genes, the exposure to pesticides may increase the risk of developing Parkinson's disease by two to six times; mainly because pesticides trigger an effect on the enzymes of ALDH which are involved in processing the brain chemical dopamine.

It is indicated that a person with Parkinson's disease has abnormally low dopamine levels owing to dopaminergic neurons which have died. At present there is no cure, but a variety of medications can provide dramatic relief from the symptoms. Patients are usually given levodopa combined with carbidopa, which delay the conversion of levodopa into dopamine until reaching the brain.

This study indicates that the velvet bean can make a medical contribution, owing to the seed which contains high concentrations of L-dopa (3,4-dihydroxy-L-phenylalanine) as well as concentrations of serotonin found in the pods, leaves and fruits. This L-dopa is metabolised from L-tyrosine, an amino acid naturally occurring in the human body, which is the immediate precursor of and converted to dopamine in the brain. Therefore, the most beneficial medical use of this supplement is in the treatment of the degenerative disorder of Parkinson's disease.

The next chapter takes the reader through a series of calculations which prove and underline the economic contributions of the velvet bean as far as its nitrogen value is concerned.

5.3.4 Chapter 4 — Southern African smallholder maize-based systems are complex and involve several crops and animals being produced to meet several needs. Therefore, a new soil fertility technology has to be integrated into the existing farming system and has to offer something new. The research problem was to examine the competitive environment of the velvet bean, and to determine whether the bean is suited as an economic replenishment of needed nitrogen to cash crops; also to use the bean as a business management tool as resource for poor farmers who cultivate in different types of agro-ecological zones in the country.

With reference to the question posted in section 1.4.1, the reader can see throughout this chapter that the velvet bean compares superior in terms of competitive advantage, compared to soybeans and dry beans. By optimising input allocation, farmers can foster adoption of the bean. As a legume it can be utilised as a crop, green manure or cover crop and/or feed itself. As a crop the velvet bean contributes the amount of 98 kg N/ha or R1 659,14/ha in rand value. With input costs that are driven by higher oil prices, as a green manure or cover crop the N contribution is even more significant. The velvet bean contributes N to the equivalent of 4,81 t/ha of maize yield, almost equal to the national average without any additional fertiliser being applied to a crop.

Even partial savings in the industry can result in huge savings for the country, contributing to positive trade balances. The conclusion on the velvet bean is that commercial and emerging farmers who cannot afford fertilisers and/or herbicides would benefit from growing the bean compared to maize mono-cropping, or by simply abandoning the field to natural fallow. The velvet bean needs to be targeted to where it will grow well and give maximum N benefit, such as otherwise fertile soils.

Ultimately, farmers should develop and use their decision-support guides, blending knowledge and decision-making with crop productivity and residue-decomposition data; to select a legume and other organic inputs together with their management for cropping systems, soil types and environments.

5.4. Limitations of the research

When conducting this study, two limitations were identified; firstly, only a literature overview about the velvet bean was conducted without conducting an empirical research questionnaire. Given the evidence that only three listings were found of research work being done on the bean within South Africa, it is of concern how farmers as well as the market will receive the velvet bean.

Secondly, it has not been identified how to formulate a production strategy after assessing the external environment of the velvet bean and how to choose a marketing strategy to introduce the bean.

5.5. Scope for further research

This list intends to indicate the needed production information with regard to the velvet bean; further research should address the following issues:

1. A study should be undertaken about the biophysical constraints that will affect the integration of the velvet bean into current commodity production systems as perceived by farmers; assisting researchers to identify the major non-adoption factors and prioritising them in relation to socio-economic categories.
2. A study should be undertaken which could assist farmers and researchers to identify the velvet bean as a compatible legume within existing spatial and temporal niches — as well as about the benefit of the appropriateness of the velvet bean for emerging farming systems as a short-term technology.
3. An *ex ante* market study should be undertaken on the velvet bean as a commodity, with reference to detailed economic analysis by;
 - assessing the market demand for the bean, within its effect of inter-cropping versus rotation issues, before it is promoted into the production system; and
 - what marginal increment or yield gain is necessary for a farmer to take up this technology - referring to agro-ecological factors, investment trade-offs such as prices, returns, risks and the influence of rapid market changes.
4. Market research — to determine the potential demand for the seed as a commodity, either for humans and/or animals; with specific reference to human medicinal use.

5.6. Recommendations

Now that the reader or farmers are aware of this technology, what is the way forward? Integrating the velvet bean into production systems is complex and will require a participatory approach which will address both the biophysical (adaptability into the specific agro-ecology), and socio-economic constraints and opportunities of farmers (landownership, market value and trade-offs for various uses). This may help to identify niches, to modify the existing production systems and to promote this technology for wider use. A diagrammatic sketch to translate the velvet-bean concept into an operational model is illustrated in Figure 5.1.

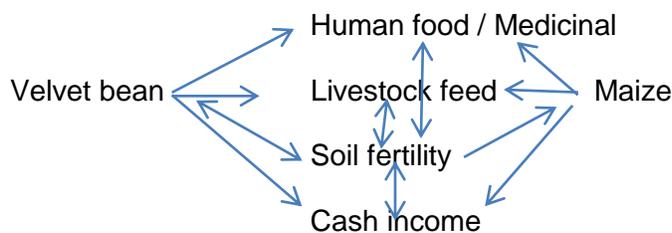


Figure 5.1 Velvet bean links to food security in a maize-based production system (Source: Author)

Future emphasis on velvet-bean research and development is important because increased production can enhance the contribution of biological nitrogen fixation to agriculture, and can occupy various niches in the market, farms and agro-ecozones. However, because contributed N often has low recovery, it is important for farmers to understand the major mechanism of this lost N to help improve the management of biologically fixed N.

As mentioned before, it is important that farmers are willing to adopt story of the velvet bean as an alternative to rising production costs. Therefore it is important to take note of the following factors which will influence decisions of farmers to convert to the velvet bean;

- i) Realise the inverse relationship which exists between production volumes and price, which makes maize and legumes substitute commodities in terms of production, as illustrated in Figure 5.2.

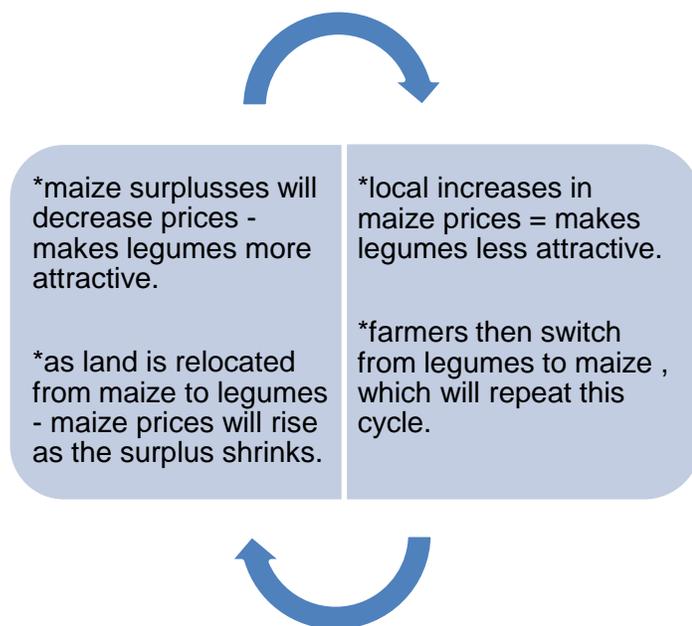


Figure 5.2 Inverse relationship between production volumes and price

(Source: Author)

- ii) Economics that will influence decisions; where the decision to plant the velvet bean will depend on profitability and the price relations to other crops.
- iii) Other factors that will influence decisions; with reference to benefits from crop-rotation practices, ranging from lower input costs and higher yields for the following crop, as well as diversification strategies.

Illustrated in table format (Table 5.2.) are recommendations on how to promote the planting and use of velvet beans as a new commodity.

Table 5.2 Constraints and recommended actions

Constraints	Recommended action
<p>1: Lack of land allocated to the velvet bean by adopting a dualist approach</p> <ul style="list-style-type: none"> • Design a new production system for commodity farmers with a larger legume component • Researchers and farmers must understand various farming systems and by identifying the existing temporal and spatial niches, new potential niches can be created by facilitating integration of the velvet bean by offering options whilst acknowledging diversities 	<ul style="list-style-type: none"> i) Rotational benefits are often more than just extra nitrogen contribution — encourage use of crop rotation ii) Encourage the planting of velvet beans by new farmers, who acquired land as a result of Land Reform iii) Encourage the planting of velvet beans by current smallholders by unlocking agronomic best practices iv) Encourage partnerships between commercial and smallholder farmers through bartering systems v) Research and Development, and partnerships — improved germ plasma of the velvet bean that can generate multiple benefits to address various constraints such as higher yields and shorter growth seasons vi) Supply push versus demand pull — the role of the market in creating added value for the velvet bean; even it be an artificial market
<p>2: Low acceptance of velvet beans for human consumption</p> <p>Historically, the velvet bean has not been accepted in South African diets owing to its perceived toxicity and habitual consumption patterns.</p>	<ul style="list-style-type: none"> i) Nutrition campaign of the velvet bean <ul style="list-style-type: none"> • encourage acceptance of velvet bean in diets • promoting health benefits of the velvet bean and its use as an alternative source of protein • promote use of the velvet bean as an affordable technology in poor communities linked to also producing derived products • linking government and research institutions to provide more research for new cultivars which contain lower levels of toxic substances
<p>3: Raising the economic potential for the velvet bean — micro-, meso-, and macro-environment imitations</p> <p>Initiate programmes to explore the potential of the velvet bean.</p>	<ul style="list-style-type: none"> i) Explore the potential of velvet beans as feedstock for biofuel production ii) Market potential <ul style="list-style-type: none"> • Low yields • Quality issues • Absence of farm gate prices • Lack of production information • Industry use iii) Farm constraints <ul style="list-style-type: none"> • Fit into current cropping system • Poor input market • Poor marketing

(Source: Author)

Of note is the importance for the reader to acknowledge that the decision of a farmer to integrate the velvet bean into a production system will be determined by

- i) biophysical factors such as biological productivity, the effect of incorporation on the following crop, the opportunity cost of growing the velvet bean, strong root system together with rate of decomposition and mulching capacity as a cover crop, drought resistance, feed value and soil cover rate.
- ii) Socio-economic factors such as farm size, suitability for intercropping and as stock feed, land productivity, marketability and toxicity of pods, growth season length and risk associated with growing the velvet bean.

5.7. Conclusion

It is not believed that anything being said about the velvet bean in this study is new. However, the key element that will make a difference in utilising the velvet bean strategy as an input cost saver is the acknowledgement of farmers that control of this technology remains in the hands of those commodity producers who will use the velvet bean.

Furthermore, other factors which constrain the competitiveness of the velvet bean as an industry includes the macro-environment (administered prices and by laws), meso-environment (R&D, SAFEX grading), and micro-environment (distance from and to the markets and quality of natural resources). Farmers can achieve higher cost-benefit ratios by adopting the velvet bean as a less capital-intensive strategy in response to higher input costs and towards environmental stewardship. The velvet-bean strategy is shown to be effective and more profitable than current practices, especially if compared to the risk of higher fertiliser market prices. As a benefit to the farmer, the velvet bean accumulates large amounts of biomass and nitrogen. Since nitrogen is limiting crop production, exploitation of the velvet-bean system will increase food security through higher yields, albeit dependent on soil fertility and the environment.

The conclusion of this study is that the use of the velvet bean relay crop in alternate seasons can be profitable and productive. Simultaneously, farmers should acknowledge the main factors seen to constrain the competitiveness of the velvet bean as a commodity, which include the macro-environment (cost of capital, consumer tastes and preferences), the meso-environment (industry organisation and technology), and the micro-environment (diversification strategies, nature and activities of industry organisation).

This low-cost technology can improve soil fertility to support agricultural production to ensure food security, irrespective of the natural endowment of the practiced land. However, this management system has to be adopted by willing farmers, on the basis that the savings in fertiliser investment

should be economically feasible. Farmers should be aware of this fact. Otherwise, by promoting fertilisers in farming areas where the usage does not result in markedly increased land and labour productivity will be a misdirection of scarce resources.

It is important that local consumers should have a healthy respect for the South African farmer. Researchers should also listen to the input of farmers in developing countries in the designing process and testing of a new product. If not, the velvet bean as a new technology cannot be sustainable in the long term; because the development process will undermine the crucial ingredients of sustainable development, namely self-reliance and social capital. It is further noted that various research results have shown that the velvet bean can safely and successfully be used as a substitute for both nitrogen fertiliser and soya bean in animal diets, without adversely affecting yield or animal growth performance.

Therefore, with benefits being realised in the long run, the velvet bean has great potential as a partner for and/or substituting soya beans as protein source or its biological nitrogen-fixing capabilities. But, although the adoption of the velvet bean could generate higher returns, it is still necessary for a farmer to investigate uncertainties such as responding maize yields, prices and discounting rates inherent in the net present value elements of this technology.

To conclude, the farming industry will agree that production systems use inputs and resources which are economically viable, socially acceptable and more environmentally friendly. Therefore, this study is of the view that farmers differ in their socio-economic status and may take up only those technologies which suit their respective circumstances. The reader should note that, although the velvet bean has a positive present value, a farmer may not consider this the only criterion for implementing this technology. Other criteria may be the magnitude of the net present value as well as the risk of this technology.

However, as a one-season crop and with low soil fertility, a legume should be promoted as a potential economic commodity and in this regard the use of *Mucuna pruriens*, alias the velvet bean, can be an example.

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