ADOPTION OF HIGH TUNNELS FOR TOMATO PRODUCTION IN NORTH EAST DISTRICT, BOTSWANA

DANDY BADIMO

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ABSTRACT

High tunnel technology has been heralded as the panacea to propel medium and small scale tomato production due to high levels of efficiency and the potential to support sustainable socio-economic development in the face of current daunting challenges and opportunities to which farmers respond. However, despite the comparative advantages offered by the technology, its adoption by farmers has been far less than satisfactory. A study was therefore carried out to investigate constraints and determinants of high tunnels adoption for tomato production in the North East District of Botswana. In addition, evaluation of profitability of the high tunnels technology in the study area was carried out. A questionnaire was used to elicit primary information from 119 horticultural farmers in the district. The study employed both descriptive statistics and binary probit regression model to analyze determinants of adoption of the high tunnels for tomato production. From the study, prohibitive cost of high tunnels, inadequate knowledge on high tunnels, inadequate capital and markets were identified as major constraints that hinder high tunnels adoption. The adoption of high tunnels was found to be positively influenced by years of education, access to extension and farm size, but negatively influenced by farmer's experience. The net profit for high tunnels was approximately BWP 388 783.97 (U$D 37712.05) compared to BWP 24 088.72 (U$D 2336.61) for open field in the 2015/16 production period. The study recommends tunnel designers to consider constructing the structure using local materials to cut down the startup cost. Furthermore, extension service organizations should be strengthened and the services and the extension system be improved to make their innovations relevant and up to date.

DECLARATION

I, Dandy Badimo do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor is being concurrently submitted to any other institution.

____________________________ _______________________

Dandy Badimo Date

(MSc. Candidate)

The above declaration is confirmed by;

____________________________ _______________________

Prof. R. M. J. Kadigi Date

(Supervisor)

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DEDICATION

This work is dedicated to my mom, Tjenesani Badimo, and my family at large, they are undoubtedly a great gift from God.

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LIST OF ABBREVIATIONS

BIDPA	Botswana Institute for Development Policy Analysis
BWP	Botswana Pula
CEDA	Citizen Entrepreneur Development Agency
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
ISPAAD	Integrated Support Programme of Arable Agriculture and Development
LEA	Local Enterprise Authority
NDP	National Development Plan
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
VIF	Variance Inflation Factor

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Horticulture plays a critical role in the socio-economic development of Botswana, and is considered as one of the priority areas for diversification, not only for the agricultural sector but the country's economy at large. The subsector provides real opportunities for employment creation and investment, rural poverty alleviation, and boosting the agricultural sector's contribution to the Gross Domestic Product (GDP) which has been dwindling since independence, representing a mere 2.7 percent in 2012 (Ministry of Finance and Development Planning, 2013). The contribution of the subsector to grand agricultural GDP has averaged at 18.2% for the period 2010-2012 (Sigwele *et al.*, 2015).

For the past decade, the subsector has received substantial government support, geared towards promoting its development. The major strides in that regard are the financial schemes and fruits and vegetables imports restriction systems established back in the late 1970s. The financial schemes include the Financial Assistance Policy (1987-1998), and currently the Citizen Entrepreneur Development Agency (CEDA), CEDA Young Farmers Fund, and Integrated Support Programme of Arable Agriculture and Development (ISPAAD) horticulture. Others financial supports include seasonal loans offered by National Development Bank (NDB) and the Youth Development Fund (YDF). Consequently, the sub-sector's production and productivity have improved considerably in the last decade (Moepeng, 2013), expanding from approximately 22% to 42% between 1994 and 2011 respectively (UNDP, 2013; Madisa *et al.*, 2012), with land area expanding from 407.85 ha in 1999 to 1026 ha in 2009 (Assefa, 2011). Currently, local production only affords to meet approximately 40 % of horticultural produce demand.

The sluggish growth and unsustainable commercial production of tomatoes result from shortness of the growing season and erratic weather conditions in Botswana. Further exacerbated by the effects of climate change and its likelihood on the upsurge (World Economic Forum, 2016; Field *et al*., 2014), production in an open field has become a challenge. Tomato is a warm season crop and cannot stand severe frost. The crop does well under an average monthly temperature of 21^{o} C to 23 ^{o} C but commercially it may be grown at a temperature ranging from 18^{o}C to 27^{o} C (Baliyan and Rao, 2013). For that reason, in Botswana the open field tomato production period runs from October to March and an upward demand for year round tomato, therefore, created a huge deficit. This has compelled the country to import substantial amount of tomatoes to meet the country's demand specifically from South Africa. As of 2013, Botswana was the largest market for South African tomato exports with a share of 27.8% (DAFF, 2014). These climate conditions prompted exploring other farming systems for tomato production in order to keep up with the increasing demand and high tunnels were introduced around 2005 in Botswana. Subsequently, the government of Botswana, in support of the technology, established a protected farming (greenhouse, high tunnel, net shade) incubator for tomato production in Glenn Valley in 2011 providing training as a way to facilitate the rollout of the technology (LEA, 2015).

High tunnels are plastic covered, passive solar heated houses used to modify the growing environment (Wells and Loy, 1993; Carey *et al*., 2009; Connell *et al*., 2012). There are various types of high tunnels depending on: frame structure, material of the frame and the covering material. For the case of covering materials, they can be plastic, fibre glass or glasshouses while frame materials include metal pipes, timber, and concrete.

The benefits associated with high tunnels include opportunities for season extension, improved yield and quality, crop risk reduction (weather and diseases related risk) and intensive production capabilities on the limited land area (Waterer, 2003; Connell *et al*., 2012; Drost and Wytsalucy 2014). Tomato is a common choice for cultivation under high tunnels because it can generate greater revenue compared with many other crops (Connell *et al.*, 2012). This allows for a quick recovery of the initial investment and ongoing income to sustain management expenses.

1.2 Problem Statement and Justification

Despite the benefits associated with high tunnels and establishment of a protected farming incubator for tomato production by the government seven years ago, there is still low adoption of the technology. This has resulted in stagnation of tomato value chain development and bloated the import bill of fresh tomatoes and associated products. The import bill for fresh tomatoes in 2014 and 2015 was BWP 32, 882,917.00 and BWP 33, 851,680.00 (1BWP = 0.097 U$D) respectively (Botswana Statistics, 2016). These drain the foreign exchange earnings and reverse government efforts to diversify the agricultural sector and nullify its huge investment into the subsector. High dependence on imports also makes the industry susceptible to international shocks and pests and diseases outbreak. For instance an outbreak of tomato leafy miner (*Tuta absoluta*) in 2016 in South Africa that later spread to Botswana through import of tomatoes resulted in shortage of fresh tomatoes in the country and consequently, the tomato price went high.

Previous studies carried out in Botswana have mostly focused on horticulture productivity of open field production system and experimental studies of protected farming performance at research centres and schools (Baliyan, 2014; Baliyan and Rao, 2013; Madisa, 2012). The studies did not investigate the awareness and adoption of the technologies at farm level which this study intended to address specifically focusing on high tunnel technology.

The study, therefore, investigated why there is low adoption of the high tunnels technology in North East District, Botswana. The study findings will aid refocusing of associated policy thrust and research and is consistent with key development strategies which include; Botswana Vision 2036, NDP 11 and SDGs, to achieve food security and promote sustainable agriculture. In addition, the findings will assist in bridging the information gap associated with high tunnels adoption in the North East District with potential spillover to the central district, and will be of benefit to tomato sub-sector stakeholders like extension service providers, consultants, researchers, input suppliers, traders and policy makers, who will be able to make more informed decisions.

1.3 Objectives

1.3.1 Overall objective

The overall objective of the study was to contribute to the understanding of the adoption process of the high tunnels technology for tomato production in the North East District of Botswana to inform future actions and promotional strategies.

1.3.2 Specific objectives

The specific objectives of the study were:

a) To determine the factors that influences the adoption of high tunnels in tomato production.

b) To evaluate profitability of high tunnels technology in the study area.

1.4 Hypotheses

a) High tunnel farming system adoption is not influenced by farm size, head of household education, age, gender, occupation, farmer's experience, access to extension, access to credit, and distance to the market.

b) There is no significant difference in net profit between tomato production under high tunnels and open field.

1.5 Limitation of the Study

The study covered only the North East District in Botswana instead of a broader coverage due to limitation of resources in terms of time and funds required for undertaking the study on a larger scale. For profitability analysis the study was based on past season information (i.e. 2015/16 production period), either as recorded or as recalled by respondents.

1.6 Organization of the Dissertation

The dissertation is organized into five main chapters. Chapter one presents an introduction to the problem, the main thrust of the study, objectives of the study and associated underlying assumptions. Chapter two presents the literature review, which addresses the general theory and empirical literature about the subject matter. Theories related to the study and empirical literature on adoption and factors influencing adoption of high tunnel for tomato production and other new technologies are highlighted. Chapter three provides a description of methods of data collection and data sources, study area, the sampling and analysis techniques, and the conceptual framework used by the study. Chapter four presents the empirical results of the study and discussion. The final chapter gives a summary and recommendations arising from the study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Theoretical Framework

Since the classic work of Roger (1962) there has been progressive effort to explain innovations diffusion and technologies adoption. Two commonly reiterated paradigms in literature include; innovation diffusion and economic constraints paradigms (Ibrahim *et al.*, 2012; Ramaeker *et al.*, 2013; Kassa *et al.*, 2014). The innovation diffusion model, following from the work of Rogers, holds that access to information about an innovation is the key factor determining the adoption decision. The paradigm recognize that adoption is a multi-stage process of collecting information, revising opinions and reassessing decisions, and hence diffusion of innovation typically follows an S-shaped curve (Rogers, 1983). Nonetheless it fails to take individual characteristics of the adopter into account and the paradigm has previously been criticised as being “top-down” in orientation and thus lacking consideration for farm variables in its “packaging” (Roling, 1988).

The economic constraint paradigm (Aikens *et al.*, 1975) contends that economic constraints reflected in asymmetrical distribution patterns of resource endowments are the major determinants of observed adoption behaviour. Lack of access to land and capital has been demonstrated as being significant constraints to adoption decisions (Havens and Flinn, 1976). Theoretical work has shown that farm size affects adoption decisions through the availability of some “threshold” hectarage where innovations occur. The strength of the economic paradigm is the recognition of the importance of profitability and economic constraints to explain adoption behaviour, but it fails to recognize less tangible factors such as personal motivation or peer pressure (Prager and Posthumus 2010).

However, another paradigm gaining attention is the 'adopter perception' paradigm in agricultural economics (Apata, 2011; Murage *et al.*, 2015), which suggests that the perceived attributes of innovations condition adoption behaviour. Perception is determined by personal factors as well as physical factors of the land and institutional factors (e.g. raising awareness through extension).

Hence, the study blended the three paradigms to reduce biasness in explaining adoption decision of high tunnels. It was assumed that the number of adopters of the high tunnels would increase as the information diffused in the study area and this would be highly correlated to awareness of the technology costs and benefits as well as heighten technological know-how, which was expected to differ across the farmers. This justified the application of the innovation diffusion theory in this study. High tunnels adoption involves a huge startup capital especially for small scale farmers therefore, it was assumed that the farmers with more assets such as farm land and income from horticulture would be more likely to invest in high tunnels more than those with less or few assets, thus the applicability of the economic constraints model. Likewise, it was assumed that a farmer would adopt the high tunnels as long as s/he perceived it to be of high benefit. On the basis of that argument the perception model was also applicable in the study.

2.2 Empirical Literature

2.2.1 Tomato production in Botswana

Tomato (*Solanum lycopersicum*) is a versatile fruit consumed in diverse ways including raw (salads), as an ingredient in many dishes and sauces, making it the most consumed fruit in the country. Tomato was the second largest imported vegetable after potatoes in

2015 and the import bill was BWP 33, 851 680.00, with a net weight of approximately 5 000 metric tonnes (Statistics Botswana, 2016b).

Tomato production is mainly a small and medium holder activity and provides income to farmers and related agencies involved in production and marketing. In Botswana, small-medium farms are located closer to rivers as there are the main sources of fresh water for irrigation, except in Glenn Valley where secondary treated waste water is used, with 47 farms covering an area of 203 ha (Areola *et al.*, 2011; Bidpa, 2012). Over the past years tomato productivity ranged from 60 -100 tons per hectare depending on the variety and related production conditions (Isaac *et al.*, 2006). As for the North East District, the average yield per hectare for open field was estimated at approximately 40 ton/ha. The total area under cultivation has been fluctuating in response to factors such as market availability, production cost, pests and diseases etc. However, the demand for tomato has been on the raise, with output decreasing which created a deficit and has warranted importation to meet the country's demand (Baliyan and Rao, 2013). The estimated tomato demand for Botswana was standing at about 12 000 tonnes per month, so the country imported most of the fresh tomatoes from South Africa to meet the supply deficit.

Tomatoes in Botswana are marketed through fresh produce markets and chain stores, where from the farm-gate they reach retailers and through wholesalers or they are directly sold to retailers by producers. Some producers sell directly to consumers. Producers either transport tomatoes to the wholesalers and retailers or wholesalers go directly to the farm-gate to buy from the producers.

2.2.2 Agriculture technology adoption

The use of science, technology and innovation have been heralded as the panacea to propel agriculture to high levels of efficiency and the potential to support sustainable socio-economic development in the face of current daunting challenges and opportunities to which farmers respond. These challenges include; climate change, population growth, changing food consumption patterns, natural resource scarcity, and global economic restructuring (Palombi *et al.*, 2013; Union, 2014). Technology adoption in agriculture in the past has evolved around increasing production, productivity and profits (FAO, 2013), which encompass fertilizers, pesticides and herbicides application and the use of hybrid seeds among others. These changed enormously in context of the on-going agricultural policy reforms, trade liberalization and multilateral environmental agreements and instigated the sustainable agriculture paradigm. Sustainable farming system refers to the capacity of agriculture over time to contribute to overall welfare by providing sufficient food and other goods and services in ways that are economically efficient and profitable, socially responsible, while also improving environmental quality (Palombi *et al.*, 2013). Therefore, the scope of technology adoption shifted slightly and priorities include biological pest controls, biotechnologies, information technologies, bioremediation, precision farming, integrated and organic farming systems as well as protected or greenhouse farming (Chiputwa *et al.*, 2011; FAO, 2013; Ngwira *et al.*, 2014).

2.2.3 Adoption of high tunnels

The tomato sub-sector worldwide is among the fast evolving sub-sectors due to aforementioned reasons and conditions. With pressing need to meet the ever rising heterogeneous tomato demand, various production technologies have been developed to ensure adequate and good quality tomato supply, and sustainable production. An increased number of tomato farmers in various countries and continents are moving towards protected farming. Protected farming vary from shade netting and simple film plastics (passive protected cultivation) to structures with glass or rigid sheet plastic equipped with sophisticated environmental controls (Palombi *et al.*, 2013; Baliyan, 2014).

The level of investment in technology (simple or sophisticated greenhouses and equipment), as well as management, depends primarily on the local climate.

The technology has been rapidly spreading across the continents for production of various crops and currently is extensively used in Middle East and Europe for production of melons, tomatoes, strawberries, cucumber, green beans and other high value crops (Waterer, 2003; Connell *et al*., 2012; Drost and Wytsalucy, 2014). The main greenhouse types in Mediterranean or Southern, less cold areas are the local type and plastic-covered industrial-type (high tunnels) greenhouses, with moderate investments and little (if any) climate control system besides natural ventilation (Castilla, 2005). In Africa, specifically in Kenya simple plastic high tunnels made of timber and polythene sheets have gained prominence among small-scale tomato farmers (Odame, 2009). Moreover, in Nigeria bamboo greenhouse are on the rise for protection of crops from unpredictable weather conditions. In Botswana high tunnels surfaced around 2005 and the government established a high tunnels incubator for tomato production in 2011 (LEA, 2015).

The high tunnels technology is largely associated with increased marketing opportunities, improved early cash flow, and high yield in tomato production (Hunter *et al.*, 2012). Reiterated by various authors, Connell *et al.* (2012), Palombi *et al.* (2013) and LEA (2015), high tunnels technology is also said to be relatively inexpensive due to the fact that is passively heated and cooled, slashing hugely from the fixed cost associated with energy use, therefore is relatively suitable for small-medium farmers. Moreover, the structure is relevant to climate change adaptation and eco-sustainable agriculture; increases productivity while reducing environmental impacts. High tunnels technology helps protect plants from cold injuries and maintain optimal growing temperatures.

Nonetheless, daily ventilation may be necessary to prevent temperatures from exceeding the optimal range.

2.2.4 Factors that influence technology adoption

There is an inexhaustible body of literature on new technologies adoption and various models have been employed. The most frequently employed dichotomous models for technology adoption decision in literature comprise of Probit, and Logit (Howley and Heanue, 2012; Ibrahim *et al*., 2012; D'Antoni *et al*., 2012; Aubert *et al*., 2013; Kassa *et al*., 2014; Labaran, 2015). The models are quite appropriate in analyzing cross sectional data with binary dependent variable. Significant difference between the two models is attached to the tails (Gujarati, 2004). Lack of flexibility and normality assumption by probit models make it sometimes less preferred especially when dealing with large sample size in favour of Logit models. Hosmer and Lemeshew (2000) highlighted that logit model has got advantage over probit in the analyses of dichotomous outcome variables because is flexible and easily used model from mathematical point of view. Ajewole (2010) indicated that the use of probit-logit methodology, nonetheless, forgo valuable information of variables under consideration because of the use of a dummy instead of a continuous variable, and does not provide information on the use intensity on adoption of a given alternative. Therefore a common model used for adoption intensity is Tobit (Adesina and Zinnah, 1993; Mpangwa, 2011). This model is also known as censored regression model because some observations on the regress are known. Therefore, based on literature, sample size, nature of the data and trial results from the two models, probit model was chosen and employed to estimate factors that condition adoption of the high tunnels technology.

Several factors have been found to influence the adoption of new technologies. These factors have been classified general into four broad categories namely; demographic, institutional, environmental and farmers perception on agricultural technology. Major factors that consistently surface from various literature as key determinates include; gender, education, age, experience, and marriage status (demographic factor) (Aubert *et al.*, 2013; Labaran, 2015), land size, wealth or asset accumulation, in-farm and on-farm income, institutional factors; extension services, input and output market access, credit facilities, land tenure system as well as information and communication infrastructure. Farmers' perception is also regarded a crucial factor associated with evaluation of the technology's attributes in terms of usefulness, easy to work with, cost saving and farmers objective.

A study by Mwangi (2012) on comparative analysis of greenhouse versus open-field small-scale tomato production in Nakuru-North District, Kenya used binary logit model and the results indicated that the decision to adopt a greenhouse tomato farming system was significantly influenced by road type, land tenure, age of household head, education level of household head, access to credit, farm income, experience, labour and group membership, the findings are in line with those of Al-Shadiadeh *et al*. (2012), Aubert *et al*. (2013) and Labaran (2015).

Another study by Kassa *et al*. (2014) on adoption and impact of agricultural technologies on farm income in Ethiopia used probit and found that adoption decision of farm households is conditioned by irrigation use, land ownership right security, credit access, distance to the nearest market, plot distance from the home stead, off-farm participation and livestock which are consistent with findings from Ajewole (2010), Manda *et al*. (2015), Ramaeker *et al*. (2013).

In conclusion from reviews above, it is evident that they are various factors influencing the adoption of new technologies. These were elucidated by a number of authors and they argued that the variations emanate from heterogeneity in socio economic, geographical and environmental condition or position, under which farmers operate and the type of technology.

2.2.5 Profitability analyses

According to Barry *et al*. (1983), profitability is a measure of the relationship between the levels of profits earned during an accounting period and the level of resources committed to earn those profits. In pure capitalism, profit is regarded the engine of maximum production and efficient resource allocation (Webster, 2003). The assumption is that the owner of firm endeavor to maximize total economic profit, where economic profit is defined as the difference between total revenue and total economic cost. It serves as crucial signaling mechanism for the dynamic reallocation of scarce productive resources. Therefore, a new technology or production system can be adopted or rejected on the basis of profit level in comparison with existing systems. There are various methods that can be used to determine profitability of an enterprise and these include, gross margin, net profit, total revenue and value of production. Commonly African studies employ gross margin (Xaba and Masuku, 2013; Itam *et al*., 2014; Labaran, 2015; Kealeboga *et al*., 2017) as a proxy for profitability analyses, this emanated from negligible fixed costs associated with the production systems and poor record keeping that hinder other techniques. In conclusion, the current study employed the net profit approach as there are substantial fixed costs associated with high tunnels technology.

2.3 Conceptual Framework of the Study

Agricultural technology adoption varies from location to location usually due to disparities in agro ecology, institutional and socioeconomic factors (CIMMIYT, 1993). In addition, farmers perception of risk and profit associated with the technology have been found to be crucial in technology adoption. Therefore, these disparities make it impossible to develop one unified adoption model in technology adoption for all specific areas. Hence, the conceptual framework in Fig. 1 represents the hypothesised relationships among variables assumed to influence the adoption of the high tunnels technology in the North East District of Botswana based on the theoretical and empirical review of relevant literature. The conceptual framework showcases the specific variables representing demographic factors, institutional and market factors and farm characteristics hypothesized to influence the adoption of high tunnels technology.

In relation to the theoretical framework that guided the study, the adoption theory is relevant and reflected in the conceptual framework because the demographic factors, institutional and market factors can potentially influence the adoption of new technology. For instance, availability and access to extension services facilitate information dissemination of the new technology and subsequently farmers can decide whether to adopt the technology or not. On the other hand, head of households' education, age and farming experience can determine the responsiveness to new technologies by farmers. The farm characteristics are also applicable as they reflect the concept of asset endowment and its effect on farmers' decision of adoption of the high tunnels technology. The conceptual framework further illustrated the impacts of high tunnels adoption which are increased yield, better quality produce and less vulnerability to climatic and weather risk.

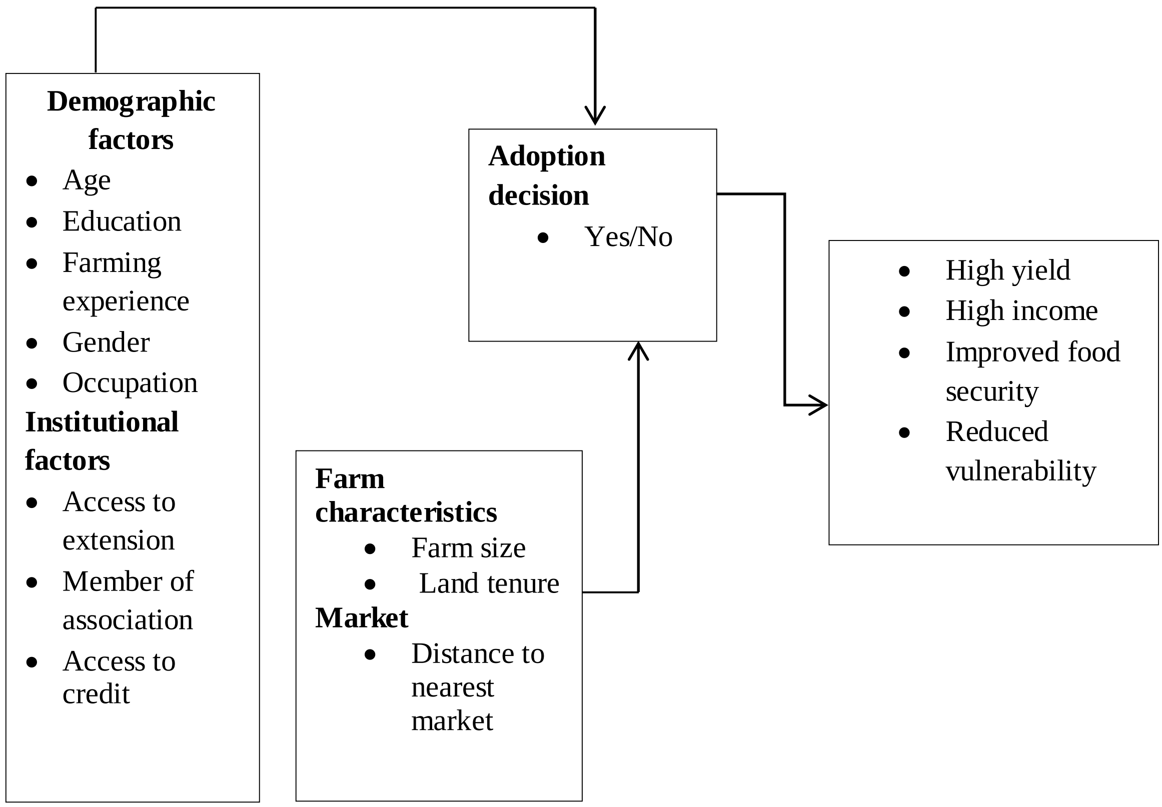

Figure 1: Conceptual Framework of the study

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the Study of Area

North East District is the second smallest district in the country. The district lies between 27'15 and 28 East (longitude) and 20'30 and 21'25 South (latitude) (North East District Development Plan 6, 2004). It covers a total area of 5 120 km^2, with a population of 167 500 (CSO, 2011). Agriculture is the predominant economic activity in the district, with a large number of households dependent on it, participating either in horticulture, pastoral farming and/or rain-fed arable farming. Other economic activities include transport and communication, finance, public administration and manufacturing.

The minimum and maximum temperatures in the district in winter reaches 5 ^oC and 23 ^oC, while in summer goes up to 17 ^oC and 30 ^oC, respectively (Department of Meteorology Service, 2017). Annual average rainfall in the district ranges between 400 mm (in the south) and 500 mm (in the north) and is around October to March (North East District Development Plan 6, 2004).

North East District is generally flat with an elevation of 930m in the South to 1300 m in the North above sea level. The district is mainly characterized by silty sands and sandy clays with a predominant light brown to brown colour which are basically from igneous and metamorphic rocks (Ranganai *et al*., 2015). The soils are well drained and moderately deep with medium texture.

The district is regarded a principal horticultural area because of its positioning as it lies between two rivers, Shashe and Ramokgwebana, which are the main sources of water for horticultural production and majority of the farms in the district are located adjacent to these rivers. As of 2011, the district had a total of 271 horticultural farmers (CSO, 2011).

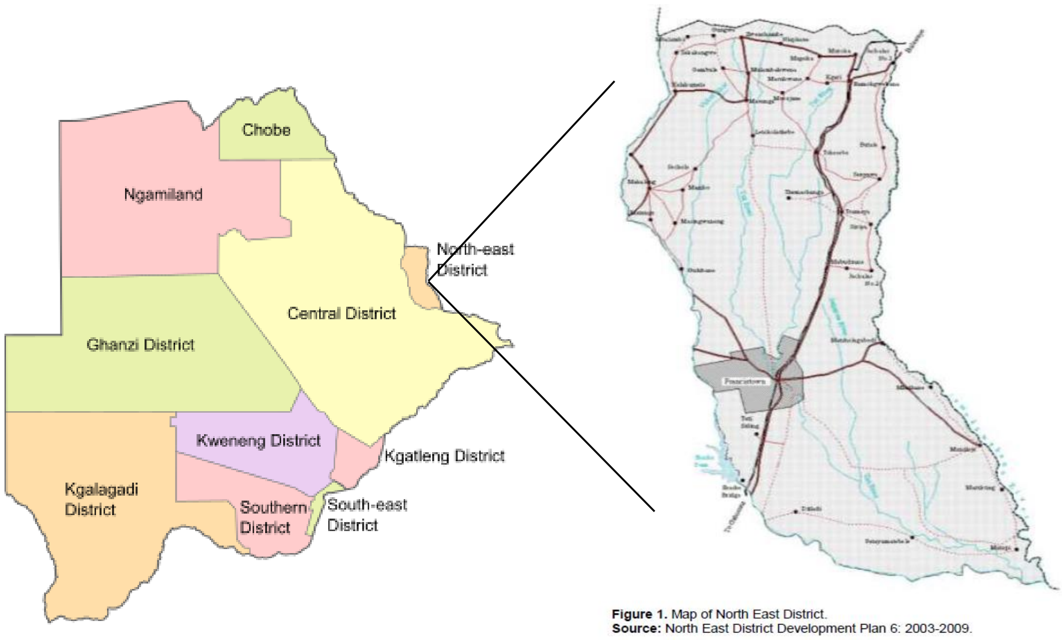

Figure 2: Map showing the location of North East District in Botswana

Source: North East District Development Plan

3.2 Research Design

A cross sectional research design was used in the survey. Data was collected at a single point in time and the data was used in descriptive analysis and for determination of relationships between variables.

3.3 Data Source and Sampling Design

3.3.1 Data source

A combination of primary and secondary data was used in the study. Sources of secondary data were relevant published literature and official project reports. A household survey was the source of primary data for the study and it entailed administering a pretested questionnaire to sampled horticultural farmers in the district with the help of trained enumerators.

3.3.2 Sampling design

Stratified random sampling technique was used for the study. The first stage was purposive sampling of North East District which is a major horticultural area in the country, strategically located relatively closer to major market out-lets, e.g. Francistown city, and lies between two big rivers in the country. The target population of the study included all horticultural farmers, constituting both small and medium-scale tomato farmers. The unit of research was the farm household. With the assistance from the Ministry of Agricultural Development and Food Security, an up to date sampling frame was prepared. Horticulture farmers in the district were segregated into two strata, non-tunnels adopters and tunnels adopters. For non-adopters a random sampling was employed to choose respondents and for high tunnels adopters, a census was carried out due to their small number.

A disproportionate stratified sample design of tomato producers in relation to their production systems implied that descriptive results would not be a true representative of the population in the study area. To compensate for that, the descriptive analysis used sampling weights. Sampling weights weigh sample data to correct for the disproportionality of the sample with respect to the target population of interest. Therefore, the data was weighted to avoid sampling bias so as to make it a representative of its population, before analyzing. Following Pfeffermann (1995), the weighting factor was obtained as the population proportion of the stratum divided by the sample proportion of the number of farmers in that stratum, expressed as: Weight factor = (% stratum in population / % stratum in sample).

3.3.3 Sample size

The sample size was decided based on the United Nations (2005) handbook for designing household survey samples, and was estimated as:

$n_h = (z^2)(r)(1-r)(f)(k)/(p)(\breve{n})(e^2)$

Where n_h is the number of households, r is an estimate of a key indicator to be measured, f is the sample design effect, k is a multiplier to account for non-response, p is the proportion of the target population in the entire population, $\breve{n}$ is the average household size and e is the margin of error to be attained.

Recommended values for some of the parameters are; the z-statistic to use should be 1.96 for the 95-percent level of confidence (as opposed to, say, 1.645, for the 90-percent level). The former is generally regarded as the standard for assigning the degree of confidence desired in assessing the margin of error in household surveys. The default value of f, the sample design effect, should be set at 2.0 unless there is supporting empirical data from previous or related surveys that suggest a different value. The non-response multiplier, k, should be chosen to reflect the country's own experience with non-response A value of 1.1 for k, therefore, would be a conservative choice. For the margin of error, e, it is recommended to set the level of precision at 10 percent of r; thus e = 0.10r (United Nations, 2005). According to the Central Statistics Office (2011), average household size in Botswana was 3 people. The proportion of the total population accounted for by horticultural farmers in the district was 15% (Statistics Botswana, 2014). According to the North East District regional office, Ministry of Agricultural development and Food Security, in 2016 tunnels adopters were estimate to be 0.11 % of horticultural farmers.

$$n_h = (3.84)(0.11)(0.961)(1.2)(1.1)/(0.15)(3)(0.01) = 119.07$$

Therefore the sample size $n_h = 119$

However, one high tunnel farmer, and two open field famers of which were found with extreme production values were excluded from the analysis. The high tunnels farmer is among the pioneers of the technology in the country, currently owning twenty tunnels, whereas for the open field farmers, the companies are owned by Chinese and South African with an annual tomato hectarage of 7 and farm size of about 27 hectares. Consequently, the analysis was based on a sample size of 116 farmers.

3.3.4 Data collection

Two primary data collection methods were employed, namely the key informants interviews (KIIs) and household survey (HHS). For household survey, a questionnaire (Appendix 1) was prepared and administered face to face to sampled farmers. The questionnaire included both open and closed-ended questions to avoid restricting the participants' answers. For the key informants' interviews, Agribusiness officers in the district, Local Enterprise Authority (LEA, Glenn Valley), and National Agricultural Processing (NAPRO) officers were purposively chosen in order to have an in-depth focus on issues important to the study. A list of questions were prepared focusing mainly on extension services and information dissemination strategies in relation to high tunnels technology, to assist obtaining necessary data from the officers. Secondary data was collected through in-depth literature review. Various ministerial reports, Statistics Botswana publications, and NDP 11 among others were reviewed. Other sources included various publications by the government, non-governmental organizations, research organizations, universities and international bodies. Secondary data was crucial to establish the key socio-economic, institutional, farm and market variables of small-scale farmers and the factors influencing technology adoption and to align study objectives with the country's main policies.

3.3.5 Data processing and analysis

Survey data were coded and summarized using Statistical Package for Social Science software version (SPPS) 16, before being transferred to STATA 13 software for analysis. Descriptive statistics such as mean and standard deviation were computed and econometric analysis performed to determine factors that influence the adoption of high tunnels technology and a probit model was employed. Net profits were computed to determine differences in profitability between high tunnels adopters and non-adopters.

3.4 Analytical Framework and Empirical Model Specification

3.4.1 Socio-economic characteristics of the tomato farmers

Descriptive statistics were used to provide summary statistics related to variables of interest of the farmers and they included mean, standard deviation, counts and percentages. The Chi-square test was used to determine any association of categorical variables in relation to the high tunnels adoption status. As a result, gender, marital status, education attainment, age categories, access to extension and credit and group membership were subjected to relationship test in relation to high tunnels adoption status. Furthermore, the t-test was used to determine any statistical significance difference between the mean of the two groups, adopters and non-adopters with respect to continuous variables. The variables which were cross-examined included farm size, land allocated to tomato, distance to market, age of head of household, farmer experience, annual farmer income and number of extension visits.

3.4.2 Constraints that the hinder adoption of high tunnel technology

Descriptive statistics were used to analyze and report the key constraints that hinder the adoption of high tunnels. This was done based on cumulative frequency and hence total percentage exceeds hundred percent.

3.4.3 Factors affecting the adoption of high tunnel technology for tomato production

Theoretical Model

A probit model was employed to examine factors influencing the adoption of high tunnels. Therefore, as a necessity before econometric estimation, various econometric assumptions and post estimation tests were carried out. More often in cross sectional data sets, commonly encountered problems are multicollinearity and heteroscedasticity. To check and address the multicollinearity problem, both pair-wise correlation matrix and Variance Inflation Factor (VIF) were run to identify and drop variables that really showed significant multicollinearity problem. As a rule of thumb, values with VIF greater than 10 are often taken as a signal for the existence of multicollinearity problem in the model (Gujarati, 2004). The model had a mean VIF of 5.75 and no correlations were noticeable from the correlation matrix, hence concluding that multicollinearity was not a problem. Heteroscedasticity problem was tested using the Breusch-Pagen test (hettest), and failed to reject the null hypothesis of constant variance. Therefore, the model was estimated with robust standard errors to correct for heteroscedasticity and other misspecification problems.

As binary model, there were two alternatives, either the farmer has adopted or not adopted the high tunnel technology. An individual *i* makes a decision to adopt high tunnel if the perceived net benefit associated with adoption choice is higher than the net benefit associated with decision not to adopt. The perceived net benefit by individual *ith* is usually expressed as latent model, as show below:

$$Y_i^* = \beta_0 + \beta_1 X_{i1} + ... + \beta_k X_{ik} + \varepsilon_i; \qquad \varepsilon_i = iidN(0, \sigma^2) \quad \text{.............................} (1)$$

i = 1, 2, 3…….116

Where;

Y_i* is a latent variable, is an index of unobserved variables associated with perceived net benefits of the high tunnels technology. X_{ik} is a vector of farmer's characteristics e.g. education of head of household for the *ith* farmer that influence expected net benefit and ε_i is the error term which is independently distributed random variable with mean of zero.

Latent variable is unobservable, but choice made by the individual *i* can be related to the actual decision taken by the farmer upon observing the discrete choice made as, Y_i takes two values, specified as:

$$Y_i \begin{cases} 1, & Y_i^* \geq 0 \\ 0, & Y_i^* < 0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Y_i = 1 (if farmer i adopts) and Y_i = 0 (if farmer i does not adopt). The dependent variable is adoption decision, assuming the value 1 or 0. The value 1 indicates a farmer who has adopted the high tunnels with expectation of positive net benefits whilst 0 as those who expect the negative net benefit, non-adopter. Adopters were defined as those farmers that have erected high tunnels and started production under the structure and non-adopters were defined as those farmers that do not have the structure and undertook tomato production in open field.

Thus the model is expressed as follows in terms of probability formula:

$$\begin{aligned} & Y_i = 1, \quad Y_i = 0, \quad i = 1,2,3.......116 \\ & if \quad \Pr[Y_i = 1|X] = \Pr[Y^* \geq 0|X] \\ & \Pr(1) = \Pr[X_i{}'\beta + \varepsilon_i \geq 0|X] \\ & \Pr(1) = \Pr[\varepsilon_i \geq -X_i\beta] \\ & \Pr(1) = \Phi(X_i'\beta) \quad given \quad \sigma = 1 \end{aligned} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where Φ is the cumulative distribution function of standard normal distribution. β is the parameters that are estimated by maximum likelihood method and x' is a vector of exogenous variables that explains adoption of high tunnels.

Therefore, the model was specified as:

$$HTAdoption = \beta_o + \beta_1 FarmSiz + \beta_2 DstMrkt + \beta_3 FarmerOcc + \beta_4 NoEduYrs$$

$$+ \beta_5 Male + \beta_6 AcCredit + \beta_7 AccEXT + \beta_8 FamExp + \beta_9 Medaged + \beta_{10} Oldaged + \varepsilon_i \quad \text{..... (4)}$$

The dependent variable: High tunnels adoption (HT Adoption): the variable takes value of 1 for the household who grew tomatoes under high tunnels during the survey and 0 for the household that produced in open field.

Independent variables: are those variables hypothesized to influence the adoption of high tunnels. Based on the reviewed adoption literature, past research findings and experience, only ten potential explanatory variables were considered for the study and examined for their influence on farmers' adoption decision of high tunnels.

Demographic Characteristics

Age of head household: measured as dummy because currently financial institutions and the government have distinct age group financial support portfolios, e.g. through CEDA Young Farmers Funds, the government of Botswana support only age category of 18-35 years, termed 'youth'.

In literature age of the household head have contention on the direction of the effect on adoption. Adults have a positive relationship stem from the fact that farmers accumulate knowledge from years of observation and experimenting with various technologies. On the other hand, Labaran (2015) pointed out that since the adoption of high initial capital technology pay-offs occur over a long period of time, while costs occur in the earlier phases, older farmers tend to be conservative and resist consumption of new technologies. Conversely, youth farmers are expected to be positively related to the adoption of high tunnels because they are still vibrant and usually educated. However, lack experience and accumulated wealth hold them back. Middle aged farmers have been found to dominate horticulture in various countries, farmers in that category have accumulated enough assets and experience that aid them to make sound decisions and are the target candidates in credit markets. Therefore, falling in middle age and old age category is expected to be positively related with high tunnels adoption relative to youth category.

Farmer experience: Farmer experience was measured as a continuous variable, being the number of years one has been involved in tomato production. Well experienced farmers were hypothesized to have a positive influence on new technologies adoption. Years of observation, experimenting and accumulated knowledge of various production systems can result in less resistance to adopt new technology from experienced farmers.

Education: Education variable was measured as a dummy, categorized as per educational qualification level, no education, primary, secondary and tertiary. This was based on an assumption that educational impact on interpreting and understanding information intensive technologies can be realized effectively based on educational categories than number of years of schooling, for instance, a secondary school graduate is assumed to comprehend information better than a primary graduate, but they is less significant difference within the category.

Education believed to reduce the amount of complexity perceived in a technology and gives farmers the ability to perceive, interpret and respond to new information much faster than their counterparts without education; hence a positive influence of high education level was expected on the adoption of high tunnels. Aubert *et al.* (2013) found that the more the grower was educated, the more s/he implemented Integrated Pest Management (IPM) practices.

Gender: measured as dummy and being male was hypothesized to be positively related to high tunnels adoption. Gender variable have been extensively investigated and, male headed household often have positive relationship because man are said to have edge in access to resources than women. Nonetheless, the gender variables show conflicting effect in literature on adoption, suggesting that the effects of gender on the adoption decision are location specific, highly dependent on culture and scale of production. A study by Kealeboga *et al.* (2017) on backyard vegetable production in Southern District, Botswana, for example, revealed that females were the dominant group, which might emphasize their decision making effect in such undertaking.

Occupation of the head of household: measured as dummy, 1 if the head of household was a full time employee in government or private institution and 0 otherwise. This variable has conflicting findings in literature. Formal employment either in government or private sector, was assumed to reduce liquidity problem when the farmer intending to purchase high tunnels as one can access a loan against his/her salary. But as for farmer financial institutions have less confidence in them due to the risk associated with agricultural enterprises and it usually takes a lot for a farmer to prove his/her credit worth or loan repayment capacity.

Farm characteristics

Farm size: Farm size was expected to have a positive relationship with the adoption of high tunnels. Larger farm owners can allocate or spare some land for high tunnel technology and still have some to counter for associated risk of the technology. With small farms, it has been argued that large fixed costs become a constraint to technology adoption (Abara and Singh, 1993) especially if the technology requires a substantial amount of initial set-up cost, so-called lumpy technology, and the technology is mostly adopted by large scale farmers.

Institutional characteristics

Access to credit: It is a categorical variable; 1 represented a household who had credit access and 0 otherwise. High startup capital is often prohibitive especially to small-scale farmers; therefore access to credit was expected to be positively related to the adoption of tunnels. Kassa *et al.* (2014) emphasized that the more farmers have access to source of finance, the more they are likely to adopt agricultural technologies.

Access to extension: measured as a dummy variable, 1 represented a household that received high tunnel technology information from extension agents and 0 otherwise. Access to information and extension services was expected to have a positive relationship with the adoption of high tunnels production system. Information reduces the uncertainty about a technology's performance hence changing individual's assessment from purely subjective to objective over time. Farmers' who were visited by extension agents were believed to have been exposed and gained useful information and, subsequently, they adopted chemical fertilizers (Wondimagegn *et al.*, 2011) leading to increased agricultural production that finally impacted their farm incomes.

Distance to the market: measured as continuous variable, the distance of the farm from the nearest market. The distant the farm was from the market implied more cost associated with transport and delayed access to market information. In that regard, the distant the farm was from the market, the farmer was assumed to be less likely to invest in high tunnel technology.

Table 1: Explanatory variables for the high tunnel adoption decision

Variable	**Variable description**	**Nature**	**Expected sign**
Age (MedAged=1, Old=1)	Age of Household	Dummy	+/-
Gender (Male=1)	Gender of head of household	Dummy	+
NoEDUYrs	Education of head of household	Dummy	+
Dist Mrkt	Distance to the market (Km)	Number	-
Farm EXP	Farming experience (Years)	Numbers	+
AcCredit (yes=1)	Access to credit	Dummy	+
EXT(yes=1)	Access to extension service	Dummy	+
Farm Size	Farm size in hectares (*ha*)	Number	+
Occ (Informal employment=1)	Farm owner's occupation	Dummy	+

In order to get a sensible interpretation of coefficients of independent variables related to the adoption of high tunnel technology, the marginal effects were computed. The marginal effect of a variable is the effect of unit change of that variable on the probability of $\Pr\left[Y_i = 1 \middle| X\right]$, given that other variables are kept constant.

The marginal effect is expressed as: $\frac{\partial \Pr(Y_i = 1 | X_i)}{\partial X_i} = \frac{\partial E\left(Y_i / X_i\right)}{\partial X_i} = \varphi(X_i' \beta)\beta$ …………(5)

3.5 Profitability Analyses

The study employed net profit to determine and evaluate the profitability levels of both high tunnel adopters and open-field/non-adopters for tomato production. The model for net profit was specified as:

$$\pi_i = TR_i - TC_i \qquad (6)$$

Where: π is the Net Profit; TR is Total Revenue; and TC is Total Cost.

Total revenue was computed from the average price of tomatoes multiplied by the quantity of consumable tomato. Quantity of consumable tomato included total marketed, consumed at household level, or donated in-kind. Direct and measurable return was obtained from the sale of tomatoes; therefore the study based it's calculation on the 2015/2016 production records.

Variable costs included inputs and costs for casual labour incurred in the production period. The costs were calculated as the product of the unit input cost and the quantity of each input used in production. These incorporated inputs and casual labour costs at preparation, production, harvesting and marketing phases. Inputs included: seeds/seedlings, fertilizers, chemicals and energy (electricity or diesel). Labour costs constituted the cost of land preparation, planting, weeding, training, trellising, harvesting, sorting and package, and transportation. For family labour, average wage in the locality was used as a proxy of the opportunity cost.

Fixed costs were made up of loan premium inclusive of interest of total initial investment costs and seasonal loans, insurance premium, repairs and maintenance, administrative costs and depreciation. Administrative costs have been estimated as 3 percent of Total Variable Costs. This method has been applied in most previous studies, for instance by

Engindeniz and Tuzel (2006). A straight line method was used for estimation of depreciation of the tunnel(s). Thus, Depreciation = (Asset Price – Salvage Value)/ Number of years of expected economic life. Therefore the aforementioned costs defined the total costs associated with tomato production in a given accounting period.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Awareness and Adoption of the High Tunnels Technology in the Study Area

4.1.1 Awareness of the high tunnel technology

High tunnel technology has proved to be a well-known production system in the study area, approximately 87% (Table 2) of the sampled farmers indicated that they were aware of the technology. The majority of the farmers revealed that they first saw and learnt about the high tunnel technology from early adopters in the district while some came to know about the technology from the South African horticultural farmers. In addition, some learnt about the technology through reading some kind of agricultural publications, especially farmer's magazines. Both high tunnels adopters and non-adopters reiterated the benefits and relevance of the technology to the current production challenges and opportunities.

Figure 3: Round roofed high tunnels for tomato production in the study area

Source: Survey results 2017.

The average cost of a single tunnel was BWP 665 08.03 (U$D 6451.28), and the cheapest was BWP 50 000 (U$S 4850) (Table 2). The high tunnels were mainly sourced from South Africa, because for its unavailability in the country.

Table 2: High tunnel information in the district

Variables	Response	Freq.	Percent	Cum.
High Tunnel Awareness	Yes	104	89.66	89.66
	No	12	10.34	100
Type of Tunnel	Round roofed (Arched)	31	100	100
Tunnel Frame	Metal	31	100	100
Tunnel Acquisition	South Africa	30	96.77	96.77
	Local (second hand)	1	3.23	100
	Mean	**Std. dev**	**Min**	**Max**
Cost of a Tunnel (BWP)	66 508.03	15 070.44	50 000	90 750

1BWPula = 0.097 U$D

4.1.2 Adoption of high tunnels technology in the study area

Although the majority of sampled households' were aware of the high tunnel technology, the results indicated that investment in the technology was progressing slowly, with only 26.70% had adopted the high tunnels as of 2017 in the study area (Fig. 4). The round roofed high tunnel with a metal frame was the only type adopted in the study area (Fig. 3).

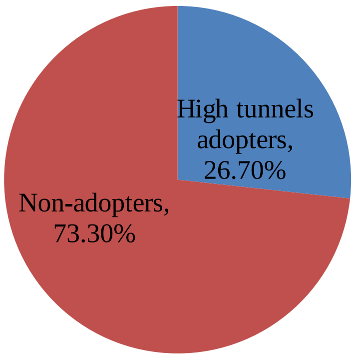

Figure 4: The adoption of the high tunnel technology in the study area

4.1.3 Trend of adopting high tunnels technology in tomato production

Adoption of the high tunnels has shown an upward trajectory despite the slow rate of adoption in the district (Fig. 5). The results are in line with the innovation diffusion theory by Roger (1983) which asserts that innovation diffusion is a multi-stage process of collecting information, revising opinions and reassessing decisions. Likewise access to information about an innovation is crucial in determining the adoption decision over time. Few adopted the technology in early years around 2010 and 2012 (3 and 2 respectively). Thereafter, following the establishment of high tunnels incubator for tomato production by LEA in 2011, the number has doubled and tripled in 2013 and 2016 respectively. This proved the significant importance and contribution of the incubator.

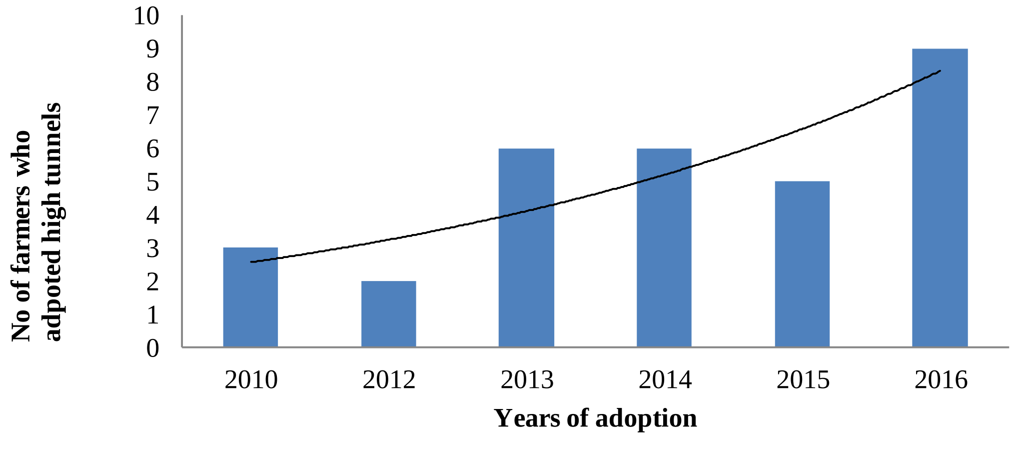

Figure 5: Trend of adoption of high tunnel technology in the study district

4.2 Socio-economic Characteristics of the High Tunnels Technology Adopters and Non-adopters

Prior to the presentation of the results of the probit model used to identify the factors that influence adoption of the high tunnels adoption, it was found sensible to compare the adopters and non-adopter of the high tunnels technology in terms of their socio-economic and institutional characteristics.

4.2.1 Demographic characteristics

Demographic characteristics of sampled households are pertinent in providing insights and a hunch about the general features of an area under investigation. So, to analyzing non-continues demographic characteristics from the study area Chi-square was employed to identify whether they is association between high tunnels adoption status and a number of chosen variables (Table 3).

Table 3: Socio-economic characteristics of the farmers

Variables			**High tunnels adoption status**				
			Adopters	**Non-adopters/ Open field**	**Total**	**Chi-Square**	**p-value**
Gender	Male	Count	14	66	80	11.2***	0.001
		%	12.10	56.90	69.00		
	Female	Count	17	19	36		
		%	14.70	16.40	31.00		
Total		Count	31	85	116		
		%	26.70	73.30	100.00		
Marital Status							
	Single	Count	6	29	35	6.929*	0.074
		%	5.20	25.00	30.20		
	Married	Count	24	47	71		
		%	20.70	40.50	61.20		
	Divorcee	Count	0	8	8		
		%	0.00	6.90	6.90		
	Widowed	Count	1	1	2		
		%	0.90	0.90	1.70		
Total		Count	31	85	116		
		%	26.70	73.30	100.00		
Educational Attainment							
	None	Count	0	1	1	36.707***	0.000
		%	0.00	0.90	0.90		
	Primary	Count	0	47	47		
		%	0.00	40.50	40.50		
	Secondary	Count	15	28	43		
		%	12.90	24.10	37.10		
	Tertiary	Count	16	9	25		
		%	13.80	7.80	21.60		
Total		Count	31	85	116		
		%	26.70	73.30	100.00		
Age							
	Youth (18-35)	Count	3	22	25	7.653**	0.022
		%	2.60	19.00	21.60		
	Mid Aged (36-59)	Count	27	51	78		
		%	23.30	44.00	67.20		
	Old Aged (>60)	Count	1	12	13		
		%	0.90	10.30	11.20		
Total		Count	31	85	116		
		%	26.70	73.30	100.00		

Source: Survey result, 2017 asterisks*, **and*** significant level at 10, 5 and 1 % respectively

From the study, males were dominant tomato producers by 69% implying that horticulture farming in the district is gender insensitive to the male sex. The result was contrary to findings by Kealeboga *et al*. (2017) on profitability of scale-farmers vegetable production in Southern District of Botswana, which found that females dominated the vegetable enterprise. Men mainly dominated the open field tomato farming category by 56.9%. Nonetheless, high tunnels tomato production was slightly dominated by females, with almost 15% females partaking in the technology compared to 12% males. From the chi-square statistic it shows that there was association between gender and type of farming at 1% significance level. The reason might be that females who venture in agriculture in Botswana are slightly educated as compared to males (Statistics Botswana, 2016a), and in that regard they comprehend new technologies information better and subsequently adopt the technology faster than their male colleagues.

In addition, the results indicated that the majority of tomato growers were married (61.2%) and this was also true for high tunnels adopters at 20.7% (Table 3). The marital status and the high tunnels adoption status were found to be correlated at 10% significance level. Tomato production is an expensive and dynamic enterprise, and therefore married couples pool their resources and ideas making them more likely to invest in such new technologies as high tunnels compared to those who are single. This study concurs with Alemaw (2014) who pointed out that married households often have capacity to manage both social and farm activities better than households who are not married.

The study revealed that a significant number of tomato growers (40.5%) have attained primary education and these were solely open field farmers. On the other hand, high tunnels adopters were secondary and tertiary graduates at 12.9% and 13.8% respectively.

A chi -square test revealed that there was a positive association between the high tunnels adoption status and education at 1% significance level. The high tunnels production system can be a complex and challenging production system, requiring high level of analytical skills and technical know-how for a successful undertaking. This confirmed that the farmer's education level had positive effect on the decision to adopt the high tunnels and the study concurs with Lapar and Ehui (2004) who argued that educated farmers are generally more open to innovative ideas and new technologies that promote technical change.

It is imperative to note that tomato production was dominated by middle aged (36-59 years) farmers in the study area at 67.2% and the least (11.2%) were in the age bracket of over 60 years of age. The results implied that tomato producers fell within the productive age (middle age) where they can actively participate in production and economic activities. In spite of the Youth Development Fund and Young Farmers Fund, only a small number (2.3%) of youth had adopted the tunnel technology compared to 19% youth in open field tomato farming.

4.2.2 Institutional characteristics

As depicted in Table 4, 50% of sampled households mentioned that they had access to extension services, with Ministry of Agricultural Development and Food Security proclaimed to be the main extension services provider in the district. Nonetheless, the farmers expressed dissatisfaction with the extension agents as they cited that they lack technical know-how on the high tunnels technology of the extension agents. There was no association found between access to extension services and high tunnels adoption status.

Table 4: Farmers responses to access to extension service, credit and group membership

Variables			High tunnel adoption status Adopters	Non-adopters/Open-field	Total	Chi-Square	p-value
Access to extension service	Yes	Count	21	37	58	5.327	0.210
		%	18.10	31.90	50.00		
	No	Count	10	48	58		
		%	8.60	41.40	50.00		
Total		Count	31	85	116		
		%	26.70	73.30	100.00		
Access to credit							
	Yes	Count	27	26	53	29.321***	0.000
		%	23.30	22.40	45.70		
	No	Count	4	59	63		
		%	3.40	50.90	54.30		
Total		Count	31	85	116		
		%	26.70	73.30	100.00		
Group membership							
	Yes	Count	13	32	45	0.108	0.724
		%	11.40	28.10	39.50		
	.No	Count	18	51	69		
		%	15.80	44.70	60.50		
Total		Count	31	83	114		
		%	27.20	72.80	100.00		

Source: Authors' survey data, asterisks*** significant level at 1 %

Despite a number of government financial assistance programmes for horticultural farmers, the study revealed that 54.3% of farmers were disadvantaged when it comes to access to credit. The majority cited lack of collateral while others simply feared the risk associated with credit. These were also indicated in a study by Mpangwa (2011). As for high tunnels adopters, they disclosed having access to credit to purchase equipment and seasonal inputs. This emphasized the pivotal role of access to credit for new technology adoption. Investment in new climate smart and eco-friendly production systems that require substantial startup capital will only be possible through well thought financial support to the farmers. Since farmers in developing countries are in financial challenged, financial assistance is indispensable to enable them to purchase new technologies and complementary inputs.

Moreover, it is apparent that subscription to group membership was very low, with a turnout of only 39.9% (Table 4). Farmers pointed out that in the past, farmers' associations were plagued by disloyalty and embezzlement of funds, and that led to the groups collapsing.

4.2.3 Comparison between adopters and non-adopters of the high tunnels technology

The mean farm size for the tomato farmers were 5.52 and 4.53 ha for high tunnels adopters and non-adopters (open field) respectively and they were statistically different at 1%. The weighted mean (W/Mean) farm size in the study area was 4.44 *ha*. With high tunnels adopters having relatively larger plots than non-adopters. The mean area of land allocated to tomato production in the two systems were 0.17 *ha* (approx. 6 tunnels) and 0.34 *ha* for high tunnels adopters and open field respectively, and the land areas were statistically different at 1% significance level. The maximum land allocated for tomato production by non-adopters was 1 *ha* whilst for high tunnels adopters it was 0.24 *ha* (equivalence of 8 tunnels). Therefore, with current land shortage problems, the high tunnel system offers a solution for tomato production intensification in small pieces of land and is applicable to urban agriculture.

Table 5: A comparison between adopters and non-adopter of high tunnel technology

Variables	Type of farmer	N	Mean	Std. Dev	Min	Max	p-Value
Farm size (Ha)	Adopters	31	5.52	1.04	3.5	8	0.001***
	Non-adopters	85	4.53	3.11	0.86	8.6	
	W/ Mean		4.44	1.88			
Land allocated to tomato (Ha)	Adopters	31	0.17	0.07	0.03	0.24	0.000***
	Non-adopters	85	0.34	0.17	0.06	1	
	W/ Mean		0.32	0.17			
Distance to the market (km)	Adopters	30	43.37	20.02	3	58	0.395
	Non-adopters	72	45.62	13.72	22	70	
	W/ Mean		45.36	14.56			
Age of head of household	Adopters	31	41.71	7.36	34	60	0.035**
	Non-adopters	85	46.87	12.69	22	68	
	W/ Mean		46.27	12.27			
Farmer Experience	Adopters	31	4.03	1.87	1	9	0.003***
	Non-adopters	85	6.58	4.46	0	16	
	W/ Mean		6.28	4.31			
No of Extension visits	Adopters	31	4.03	3.01	0	8	0.247
	Non-adopters	84	3.25	3.27	0	10	
	W/ Mean		3.31	3.24			
Annual farm Income (BWPula)	Adopters	31	218 506.19	80 850.73	75 114	358 246	
	Non-adopters	85	119 266.48	98 618.83	14 500	473 306	0.000***
	W/ Mean		130 886.62	101 653.50			

1BWPula = 0.097. **Source:** computed from survey data, asterisks **and*** significant level at 5 and 1 % respectively

The weighted mean age of tomato farmers in the study was 46.27, with the mean ages for high tunnels adopters and non-adopters tomato farmers being approximately 41 and 47 years respectively. It signified that tomato farming in the study area was mainly a middle-aged enterprise. The results illustrated that the high tunnels adopters were relatively younger than the open-field tomato farmers and the results were statistically different at 5% (Table 5).

Annual farm income and farmer experience were also statistically different at 1%, with average farm income for high tunnels adopters approximately two times that of non-adopters. Nonetheless, distance to the market and numbers of extension visits were statistically insignificant. For distance to the market, the reason might be that land for horticulture in the district is mainly allocated adjacent to Shashe and Ramokgwebana rivers, for the farmers to utilize the river for irrigation but the rivers are relatively distant from the markets.

4.3 Constraints that Hinder Adoption of High Tunnels

Farmers were asked to indicate factors that hampered adoption of the high tunnels technology and the cost of high tunnels was mentioned as one of the major constraint at 53.8%. An average price for a single high tunnel was BWP 66 508.03 and the farmers highlighted that currently tunnels were only bought in South Africa. External sourcing of high tunnels and complementary inputs make initial capital investment on tunnels a major prohibiting factor for the adoption of the technology. Despite inclusion of high tunnels in ISPAAD farmers still believed that government contribution of 40% is not enough given the high tunnels prices.

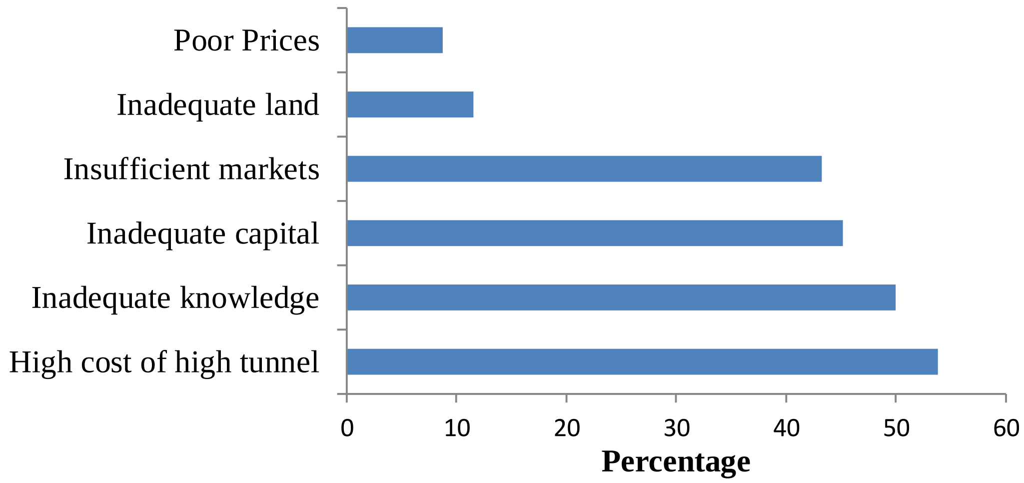

Figure 6: Factors that hinder adoption of high tunnel

Note: Frequency totals is more than 100% due to multiple responses

Yet the majority of the farmers indicating that they were aware of the production system, half of the farmers reiterated lack of knowledge especially management of crops under high tunnels production system. The sampled farmers expressed challenges of control diseases and pests such as fungus and nematodes. Surprisingly tunnels adopters also reiterated the same, especially the know-how on management of tomato under tunnels, hence during the outbreak of leaf miner (*Tuta absoluta*), the farmers were also hit hard.

Market inadequacy was also among the major constraints; with absolutely no tomato industries in the country, farmers are skeptic in investing in such a relatively costly technology, with no insurance or certainty of produce absorption by the market. The newly established processing plant demanded only 32 tonnes per month of tomatoes which was far less than the local production and only one Botswana horticulture market outlet was operational.

Farmers also expressed their dissatisfaction regarding high volumes of fresh tomatoes from South Africa even when the local produce was in abundance by big retail and chain stores operating in the country. They stated it as one factor that resulted in low prices of tomatoes in the country which was unrelated to their production cost. Market inadequacy was also pointed out by Farida and Fariya (2014), as a major marketing constraint in Ghana for tomato producers. Furthermore, farmers were less impressed by government support on the horticultural subsectors when compared to arable and livestock farming. These factors partly explained large number of farmers exiting tomato production.

Farmers in the district also attributed low adoption of the technology to lack of collateral and decried stringent credit terms and conditions at financial institutions. Small scale farmers therefore largely depended on their own meager resources which in most cases are not adequate to purchase such a technology. Farmers were less impressed by financial assistance offered by government despite the sector considered to be a potential economic diversifier. Cremades *et al.* (2015) emphasized that appropriate financial assistance is key in adoption of modern technology by farmers. Other factors indicated by farmers include inadequate land and poor prices.

4.4 Factors Influencing the Adoption of the High Tunnel Technology

Table 6: Descriptive statistics of the factors which were assumed to affect adoption of the high tunnel technology

Variable	Mean	Std. Dev.	Min	Max
HTAdopters (yes=1, otherwise=0)				
Farm size	4.44	1.88	0.86	8.60
DistMrkt	45.36	14.56	3.00	70.00
FarmEXP	6.28	4.31	0.00	16.00
EduNoYrs	10.06	3.16	0.00	16.00
AnnualIncome	130 886.62	101 653.50	14 500.00	473 306.00
EXT (yes=1, otherwise=0)	0.25	0.43	0.00	1.00
AcCredit (yes=1, otherwise=0)	0.46	0.50	0.00	1.00
GenderMale (yes=1, otherwise=0)	0.69	0.46	0.00	1.00
Old (yes=1, otherwise=0)	0.11	0.32	0.00	1.00
MedAged (yes=1, otherwise=0)	0.67	0.47	0.00	1.00

Binary probit regression results

After satisfying the probit model assumptions, estimation of factors influencing adoption of high tunnels in relation to hypothesized variables discussed in the preceding section was run. A quick glance at Table 7 attested the model significance at 1% level, with the log likelihood function Chi- squared value of 58.68. This meant that the model adequately explained the relationships between the dependent and independent variables. Consequently, the hypothesis that adoption of high tunnels is not influenced by farm size, head of household's education, occupation, farmer's experience, access to extension, access to credit, age gender and distance to the market was rejected at 0.01significance level. It implies that all explanatory variables included in the model jointly influence the adoption of high tunnels technology in the study area.

Another indicator of the model's overall fit was the estimated value of McFadden pseudo-*R2* of 0.621, which considering the cross-sectional nature of the data indicated that the model had fair predictive power.

As expected the regression results (Table 7) showed that farm size, years of education, access to extension and being middle aged (36-59) had a positive and significant relationship with the probability of adopting the high tunnel technology. However, farmer's experience, gender and distance to the market had a negative relationship with probability of high tunnel adoption, and the first two contradicted the prior assumptions. For male headed households farmers the negative relationship might stem from the fact that men are risk takers and often reluctant to adopt risk mitigating options, e.g. insurance.

Table 7: Factors influencing the adoption of high tunnel

Probit regression		**Robust**	**Marginal effects**		
Variables	Coef.	Std. Err.	dy/dx	Std. Err.	P>z
HTAdopters					
Farmsize	0.271	0.121	0.045**	0.020	0.026
EduNoYrs	0.175	0.064	0.029*	0.016	0.061
Occ2	0.018	0.750	0.003	0.127	0.981
FarmEXP	-0.140	0.080	-0.023**	0.011	0.034
EXT	1.473	0.417	0.368**	0.151	0.015
AcCredit	0.617	0.545	0.107	0.074	0.145
MedAged	1.066	0.422	0.144	0.091	0.112
Old	1.184	0.857	0.320	0.262	0.222
logDistanceMrkt	-0.301	0.322	-0.050	0.051	0.327
GenderMale	-0.705	0.444	-0.140	0.099	0.158
cons	-3.414	1.334			
No of Obs (n)	116				
Wald chi2(10)	58.68				
Prob > chi2	0.000				
Pseudo R2	0.612				
Log pseudolikelihood	-26.102				

Source: Survey result, 2017 asterisks* and** significant level at 10 and 5 % respectively

In regard to farmer's experience, the results show that a one year increase in farming experience was estimated to decrease the probability of adopting high tunnel technology by 2.3% (P>0.05), holding others things constant. From Table 4, it is evident that farmers who adopted high tunnels were less experienced in comparison to open field farmers or non-adopters. This might be derived from the fact that as a farmer gain experience in a given production system, experimenting with the system is common, leading to modify it to suit them, hence farmers are more comfortable and resist switching to new innovations. Experienced farmers often receive any radical innovation with skepticism, as they are often wary of a system or technology that is different from the one they are familiar with. This means that the risk aversion factors increases with increase in experience. The same was revealed by Mwangi (2012) that more experienced farmers were negatively associated with adoption of greenhouse tomato farming.

Years of education and farm size are estimated to increase the probability of adopting high tunnels by 2.9%, and 4.5% respectively, holding others things constant. It is worth to note that high education is assumed to relax the complexity perception of new technologies and as argued by Caswell *et al.* (2001) creates a favourable mental attitude for the acceptance of new practices, especially information-intensive and management-intensive practices. Therefore, farmers with more years of education can comprehend better such production technology and have heightened managerial ability which boosts the will to invest in sustainable production systems than those with few years of education. The result is consistent with findings by Cremades *et al*. (2014), that farmers with a higher education levels are more likely to adopt modern new technologies faster.

Medium size farms (5-10 *ha*) allow for installation of such big structures and still have enough space for other crops, this is in assent with the descriptive results in Table 4, that high tunnels adopters had larger farms compared to their open field counterparts. Usually such technology comes with complementary inputs such as a fertigation system, which allows for efficient application of fertilizer and more land is required to accommodate the whole technology. The findings are in line with various authors including Asfaw *et al.* (2016), Abara and Singh, 1993 and Akudugu *et al.* (2012). This presents a serious challenge for adoption of modern agricultural production technologies in the study area, because the majority of farm households in the district operate on small scale with average farm sizes hardly exceeding five hectares.

Access to extension has been labeled as an influential factor in various studies of new technology adoption (Cremades *et al*., 2014; Kassa *et al*., 2014; Akudugu *et al*., 2012). Unsurprisingly, the study results affirmed that the probability that farmers adopt high tunnel technology is estimated to increase by 36.8% (P>0.05) *ceteris paribus*, when extension services are accessible to the farmers. Provision of extension services makes a valuable contribution by disseminating information about the beneficial aspects of the technology and can also complement low levels of education in the overall decision to adopt certain technologies. Access to information reduces the uncertainty about a technology's performance therefore effective extension services assist to change farmers' assessment over time of the new technology thereby facilitating its adoption.

4.5 Comparison of Profitability of Tomato under High Tunnel and Open Field

Table 8: Results of profitability analysis (For comprehensive results see, Appendix 2)

	High tunnel adoption status				
	Adopters		**Non-adopters/Open-field**		
Variable	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**t-values**
Yield/Ha	83.95	32.34	15.46	16.63	14.24***
Total Revenue (BWP/*ha*)	644803.94	232866.72	107589.07	115166.67	5.33***
Total Variable Cost (BW/*ha*)	117755.12	51452.52	67066.94	38745.30	15.78***
Gross Margin/Ha	515524.19	242168.98	40522.12	118691.81	13.36***
Gross Margin/TVC	5.181	3.167	0.604	3.063	7.28***
Fixed Cost	126740.22	41516.09	16433.41	21128.56	17.80***
Net Profit	388783.97	247533.78	24088.72	118929.44	10.12***

NB: 1BWPula=0.097U$D and average prices are 1kg (BWP15), 3kg (BWP50), A crate, 22kg (BWP160), asterisks*** significant level at 1 %

Tomato production proved to be a profitable enterprise in both production systems. Nonetheless, high tunnels in the study area attested to be a highly lucrative production system compared to open field given the erratic weather and climate variability challenges faced during the production period. The mean net profit for high tunnel adopters was BWP 388 783.97 compared to BWP 24 088.72 for open field/non-adopters. From the results, therefore, the hypothesis that there are no significant differences in net profit between high tunnels technology adopters and non-adopters/open field farmers was duly rejected.

The high tunnels technology adopter's high net profit was attributed to better quality produce, premium prices in winter, and selling regularly among others. These results are consistent with various past studies (Mwangi, 2012; FAO, 2013). The mean gross margins were BWP 515 524.19/*ha* and BWP 40 522.12/*ha* for the high tunnels adopters and open-field tomato farmers, respectively. The gross margins for high tunnels adopters were therefore higher than those for the open-field system. The differences between the gross margins were statistically significant, at 1% significance level.

The mean yield for high tunnels adopters was almost six times the open field yield, with average revenue of approximately BWP 644 803.94. In spite of high profits associated with high tunnel technology there are substantial costs (BWP 244 495.34) attached to the technology compared to costs in the open field production system (BWP 83 500.35). Significant fixed costs of the open field system were from permanent labour and repair and maintenance. For variable costs, seeds and chemical inputs took a large share in high tunnels, and to contrast the open field production system energy and casual labour formed a sizable amount (Appendix 2). High seed costs were mainly from the use of expensive indeterminate tomato varieties compared to those used by open field farmers. The implication of indeterminate tomato varieties to open field is that they required regular trellising, therefore translating to high costs associated with casual labour.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary and Conclusion

The study focused on understanding the adoption of high tunnels for tomato production in North East District of Botswana using survey data sourced from 116 tomato producers. Findings from the study revealed that investment in high tunnels technology was progressing slowly, with only 26.7% having adopted the high tunnels for tomato production in the district. The adoption of the technology was reported to be largely impeded by high initial cost of the technology, lack of knowledge on high tunnels, inadequate capital and markets.

Unarguably tomato production under high tunnel was highly profitable in North East District. The high tunnels technology proved to be consistent with the current global challenges that include land shortage, erratic weather conditions, pests and diseases outbreaks and is really necessary because it has a decisive effect on production quantity and quality**.** The mean net profit of high tunnels was BWP 388 783.97 (U$D 37 712.05) compared to BWP 24 088.72 (U$D 2 336.61) for open field. As a result, the null hypothesis that there was no significance difference in net profits between high tunnels and open field farmers was rejected at 1% significance level.

Access to extension, years of education, and farm size were found to positively influence high tunnels adoption, whilst farm experience negatively influenced adoption of high tunnels in the study area. This led to rejection of the null hypothesis that adoption of high tunnels was not influenced by farm size, head of household education, occupation, farmer's experience, access to extension, access to credit, age, gender and distance to the market at 1% significance level.

Overall, these analyses clearly indicate that the adoption of high tunnels in the study area is not solely conditioned by cost of the structure; there are a number of interplaying factors of household, market, farm and institutional characteristics. In that regard, understanding and appreciating these linkages can enable effective intervention and subsequently speeding the technology adoption in the district. Moreover, addressing the aforementioned constraints will improve the adoption rate of the technology and therefore, resulting into positive impact on the tomato industry in the study area and Botswana, at large.

5.2 Recommendations

In view of major findings of the study and the above conclusion, the following recommendations are drawn:

a) Extension service was one of the variables found to have positive significant influence on adoption of the high tunnels. Therefore, strengthening and improving extension service should be a priority by government increasing the number of extension workers and provide adequate resource to enable extension agents to perform to their best. With inadequate knowledge on high tunnel technology pointed out to be a constraint, extension agents should intensify high tunnel technology information dissemination through short courses, workshops and in-field training in the district

b) Cost of the high tunnel technology was identified as one of the major constraints that hinder the adoption of high tunnels. Therefore, any measure that can help reduce the cost is vital to ensure improved adoption of the structure. Hence, the study recommends that tunnel designers should consider constructing the structure using local materials to cut down cost of the technology. This has been a success story in Kenya and Nigeria, through the use bamboo tree.

c) Both government and the private sector should establish value adding industries to help create appealing and reliable markets for the farmers and in turn can result in adoption of such production enhancing technologies like high tunnels.

d) Furthermore, education was found to positively influence the adoption of high tunnels technology, however, the majority of the farmers (40%) are of low education. This might continue to be a stumbling block to the adoption of high tunnels which is a relatively management-intensive technology. In that regard, the study recommends that farmers should consider undertaking short courses related to their enterprise offered by Botswana University of Agriculture and Natural Resource and LEA to complement their low education and enhance their technical and management skills of new technologies, in this case high tunnels.

e) Further studies, investigating the economic viability of the system in relation to current global challenges such as water scarcity, energy and chemical use is suggested.

REFERENCES

Abara, I. O. C. and Singh, S. (1993). Ethics and biases in technology adoption: The small farm argument. *Technological Forecasting and Social Change,* 43: 289-300.

Adesina, A.A. and Zinnah, M.M. (1993). Technology characteristics, farmers' perceptions, and adoption decisions: A tobit model application in Sierra Leone. *Agricultural Economics,* 9: 297-311.

Aikens, M.T., Havens, A.E. and Flinn, W.L. (1975). The adoption of innovations: the neglected role of institutional constraints. Mimeograph. Department of Rural Sociology. The Ohio State University. Columbus, Ohio. pp 279-296.

Ajewole, O. C. (2010). Farmer ' s response to adoption of commercially available organic fertilizers in Oyo state, Nigeria. *African Journal of Agricultural Research*, 5(18): 2497 – 2503.

Akudugu, M., Guo, E. and Dadzie, S. (2012). Adoption of Modern Agricultural Production Technologies by Farm Households in Ghana: What Factors Influence their Decisions? *Journal of Biology, Agriculture and Healthcare*, 2(3). ISSN 2224-3208 (Paper) ISSN 2225-093X (Online).

Alemaw, A. (2014). Impact of improved maize varieties adoption on small-holder farmers' marketed maize surplus in Oromia Regional State, Ethiopia. Unpublished Dissetation for Award of MSc. Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 96pp.

Al-Shadiadeh, A. N., AL-Mohammady, F. M. and Abu-Zahrah, T. R. (2012). Factors Influencing Adoption of Protected Tomato Farming Practices Among Farmers in Jordan Valley. *World Applied Sciences Journal,* 17(5): 572 – 578.

Apata, T. G. (2011). Factors influencing the perception and choice of adaptation measures to climate change among farmers in Nigeria Evidence from farm households in Southwest Nigeria. *Environmental Economics,* 2(4): 74 – 76.

Areola, O., Dikinya, O. and Mosime, L. (2011). Comparative effects of secondary treated wastewater irrigation on soil quality parameters under different crop types. *African Journal of Plant Science and Biotechnology,* 5: 41 – 55.

Asfaw, S., Federica, D. B. and Lipper, L. (2016). Agricultural Technology Adoption under Climate Change in the Sahel: Micro-evidence from Niger. *Journal of African Economies,* 2016: 1-33.

Aubert, M., Codron, J., Rousset, S. and Yercan, M. (2013). The Adoption of IPM Practices by Small Scale Producers: The Case of Greenhouse Tomato Growers in Turkey. In: *140th EAAE seminar, Theories and Empirical application on policy and government of agric-food chains*, Perugia, Italy 12-13 December.

Baliyan, S. P. (2014). Improving sustainable vegetable production and income through net shading: A Case Study of Botswana. *Journal of Agriculture and Sustainability,* 5(1): 70 – 103.

Baliyan, S. P. and Rao, M. S. (2013). Evaluation of tomato varieties for pest and disease adaptation and productivity in Botswana. *International Journal of Agricultural and Food Research*, 2(3): 20 – 29.

Barry, P. J., Hapkin, J. A. and Baker, C. B. (1983). *Financial Management in Agriculture*. Third edition. The Interstate Printer and publishers, Inc., Dawille, Illinois. 540pp.

Botswana Institute for Development Policy Analysis (Bidpa) (2012). A Study of the Contribution of Sustainable Natural Resource Management to Economic Growth, Poverty Eradication and Achievement of NDP 10 Goals. Case study 1: Vegetable production using treated waste water. Ministry of Finance and Development Planning, Gaborone, Botswana. 17pp.

Carey, E. C., Jett, L., Lamont, Jr. W. J., Nennich, T. T., Orzolek, M. D., Williams, K. A. (2009). Horticultural crop production in High Tunnels in the United States: A Snapshot. *HortTechnology,* 19(1): 25-36.

Castilla, N. and Hernández, J. (2005). The plastic greenhouse industry of Spain. *Chron. Horticulture,* 45(3): 15 - 20.

Caswell, M., Fuglie, K., Ingram, C., Jans, S. and. Kascak, C. (2001). Adoption of Agricultural Production Practices: Lessons Learned from the U.S. Department of Agriculture Area Studies Project. *Agricultural Economics*, 792: 116.

Central Statistics Office (2011). *Botswana Housing Statistics.* Government Printers, Gaborone, Botswana. 88pp.

Chiputwa, B., Augustine, S., Langyintuo and Wall, P. (2011). Adoption of Conservation Agriculture Technologies by Smallholder Farmers in the Shamva District of Zimbabwe: A Tobit application. *Paper accepted for the 2011 meeting of the Southern Agricultural Economics Association (SAEA) in* Texas, USA. 28pp.

CIMMYT Economics Program (1993). *The Adoption of Agricultural Technology: A Guide for Survey Design*. Mexico, D. F.: CIMMYT. 98pp.

Connell, S. O., Rivard, C., Peet, M., Harlow, C. and Louws, F. (2012). High tunnel and field production of organic heirloom tomatoes: Yield, fruit quality, disease, and microclimate. *Hortscience*, 47(9): 1283–1290.

Cremades, R., Wang, J. and Morris, J. (2015). Policies, economic incentives and the adoption of modern irrigation technology in China. *Earth Syst. Dynam*., 6: 399–410.

D'Antoni, J. M., Mishra, A. K. and Joo, H. (2012). Farmers' perception of precision technology: The case of autosteer adoption by cotton farmers. *Computers and Electronics in Agriculture*, 87: 121-128.

Department of Agriculture, Forestry and Fisheries (2014). A *Profile of the South African Tomato Market Value Chain*. Republic of South Africa. 36pp.

Department of Meteorological Services (2017). Botswana Agrometrological monthly bulletin. *Agromet Bulletin*., 2(4): 6pp.

Drost, D. and Wytsalucy, R. (2014). High Tunnel Green Bean Production. *All Current Publications*. Paper 681.

Engindeniz, S. and Tuzel, Y. (2006). Economic analysis of organic greenhouse lettuce production in Turkey. Ege University. Bornova-Izmir, Turkey. *Spanish Journal of Agricultural Research*, 63(3): 85-290.

FAO (2013). *Good Agricultural Practices for Greenhouse Vegetable Crops; Principles for Mediterranean Climate Areas.* Plant Production and Protection Paper No. 217. Food and Agriculture Organization, Rome Italy. 640pp.

Farida, A and Fariya (2014). Analysis of Production and Marketing Constraints of Tomato among Rural Farmers in Talensi Nabdam District of Upper East Region of Ghana. *IJASRT in EESs,* 4(1).

Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E., Chatterjee, M., Ebi, K. L., Estrada, Y. O., Genova, R. C. and Girma, B. (2014). International Panel on Climate Change. Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group No. 2. Intergovernmental Panel on Climate Change. 1142pp.

Greene, W. H. (2003). *Econometric Analysis*. Fifth Edition. Upper Saddle River, New Jersey, USA. 1231pp.

Gujarati, D. N. (2004). *Basic Econometrics*. Fourth Edition. New York: McGraw-Hill. 1024pp.

Havens, A. E. and Flinn, W. L. (1976). Green revolution technology and community development: The limits of action programs. *Economic Development and Cultural Change,* 23: 469-481.

Hosmer, D. W. and Lemeshow, S. (2000). *Applied Logistic Regression*. Second Edition John Wiley and Sons, Inc. 383pp.

Howley, P. and Heanue, K. (2012). Factors affecting farmers' adoption of agricultural innovations: A panel data analysis of the use of artificial insemination among dairy farmers in Ireland. *Journal of Agriculture Science,* 4(6): 171–179.

Hunter, B., Drost., D. and Black, B. (2012). Improving growth and productivity of early-season high-tunnel tomatoes with targeted temperature additions. *HortScience,* 47: 733–740.

Ibrahim, M., Florkowski, W. and Kolavalli, S. (2012). The determinants of farmer adoption of improved peanut varieties and their impact on farm income: evidence from Northern Ghana. In: *Agricultural and Applied Economics Association Annual Meeting Seattle*, 12 – 14 August 2012. pp. 1 – 16.

Isaac, B., Modisa, M., Machacha, D., Moamogwe, M. and More, K. (2006). *Manual for Vegetable Production in Botswana*. Department of Agricultural Research. Gaborone, Botswana. 64pp.

Itam, K., Ajah, E., Agbachom, E. and Emmanuel (2014). Analysis of Determinants of Cassava Production and Profitability in Akpabuyo Local Government Area of Cross River State, Nigeria. *International Business Research*, 7(12): 128.

Kassa, B., Kassa, B and Aregawi, K. (2014). Adoption and Impact of Agricultural Technologies on farm income: Evidence from Southern Tigray, Northern Ethiopia. *International Journal of Food and Agricultural Economics*, 2(4): 91 – 106.

Kealeboga, T. S., Tselaesele, T. N. and Lgat, T. J. (2017). Profitability of Small Scale Vegetable Production Southern District, Botswana. *Journal of Agricultural Studies*, (5)1.

Labaran, M. (2015). Assessing the factors influencing the adoption of bio-pesticides in vegetable production in the Ashanti Region of Ghana. Dissertation for Award of MSc Degree at Kwame Nkrumah University, Ghana. 153pp.

Lapar, M. L. A. and Ehui, S. K. (2004). Factors affecting adoption of dual-purpose forages in the Philippine uplands. *Agric. Syst*., 81: 95-114.

Lapar, M. L. A. and Ehui, S. (2003). Adoption of dual-purpose forages: some policy implications. *Trop. Grasslands,* 37: 284 – 291.

Local Enterprise Authority (LEA). (2015). *Annual Report 2014-15*. Government Printers, Gaborone, Botswana. 84pp.

Madisa, M. E. (2012). Analysis of horticultural production trends in Botswana. *Journal of Plant Studies*, 1(1): 1-11.

Madisa, M. E. and Assefa, Y. (2011). Impact of government financial incentives on peri-urban vegetable production in Botswana. *Journal of Horticulture and Forestry*, 3(8): 264–289.

Manda, J., Khonje, M., Alene, A. and Kassie, M. (2015). Analysis of Adoption and Impacts of Improved Maize Varieties in Eastern Zambia. *World Development,* 66: 695 – 706.

Ministry of Finance and Development Planning (2013). *National Development Plan*. Government Printers, Gaborone, Botswana. 391pp.

Moepeng, P. (2013). Core Economic Issues in the Horticulture Sector of Botswana. *Working Papers No. 55*. The University of Queensland, Australia. 40pp.

Mpangwa, M. (2011). Adoption and economic impacts of improved sorghum varieties in semi-arid areas of Tanzania: A Case of Singida Rural District. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 135pp.

Murage, A. W., Pittchar, J. O., Midega, C. A. O., Onyango, C. O. and Khan, Z. R. (2015). Gender specific perceptions and adoption of the climate-smart push e pull technology in eastern Africa. *Crop Protection,* 76: 83 – 91.

Mwangi, W. J. (2012). Comparative analysis of greenhouse versus open-field small-scale tomato production in nakuru-north district. Dissertation for Award of MSc Degree at Egerton University, Kenya. 88pp.

Ngwira, A., Johnsen, F. H., Aune, J. B., Mekuria, M. and Thierfelder, C. (2014). Adoption and extent of conservation agriculture practices among smallholder farmers in Malawi. *Journal of Soil and Water Conservation*, 69(2): 107-119.

North East District Development Plan 6: 2003-2009 (2004). Ministry of Local Government. Gaborone, Botswana. 193pp.

Odame P. S. (2009). *Manual on Greenhouse Technology*. Agricultural Information Resource Centre. Essensho Company Ltd. Nairobi, Kenya. 147pp.

Palombi, L. and Sessa, R. (2013). Climate-smart agriculture: sourcebook. *Climate-smart agriculture: sourcebook.* 570pp.

Pfeffermann, D. (1995). The Role of Sampling Weights when modeling survey data. *International Statistical Review*, 61(2): 317-337.

Prager, K. and Posthumus, H. (2010). Socio-Economic Factors Influencing Farmers'adoption of Soil Conservation Practices In Europe. In: Napier TL. *Human dimensions of Soil and Water Conservation*, 1(6): 203-223.

Ramaeker, L., Micheni, A., Mbogo, P., **V**anderleyden, J. and Maertens, M. (2013). Adoption of climbing beans in the central highlands of Kenya: An empirical analysis of farmers' adoption decisions. *African Journal of Agricultural Research*, 8(1): 1 – 19.

Ranganai, R. T., Moidaki, M., and King, J. G. (2015). Magnetic Susceptibility of Soils from Eastern Botswana: A Reconnaissance Survey and Potential Applications. *Journal of Geography and Geology*, 7(4): 9779-9787.

Rogers, E. (1983). *Diffusion of Innovations* (3rd Ed.) Free Press, Division of Macmillian Publishhing Co., New York. 236pp.

Roling, N. (1988). *Extension Science: Information Systems in Agricultural Development. Wye Studies in Agricultural and Rural Development*. Cambridge University Press, UK. 245pp.

Sigwele, Howard, K., Orlowski and Walter, D. (2015). *Botswana - Agriculture Public Expenditure Review* (*2000-2013*). World Bank Group, Washington, DC. 147pp.

Statistics Botswana (2014). *2012 Annual Agricultural Survey Report*. Statistics Botswana, Gaborone, Botswana. 200pp.

Statistics Botswana (2016a). *Agricultural census, starts brief 2015*. Statistics Botswana, Gaborone, Botswana. 14pp.

Statistics Botswana (2016b). *Vegetable imports 2014-2016 Report*. Statistics Botswana. Gaborone, Botswana. 10pp.

UNDP-UNEP PEI (2013). *Policy Brief, Arable Agriculture and the Case of Peri- Urban Horticulture in Botswana.* UNDP/UNEP Poverty Environment Initiative, Gaborone, Botswana. 4pp.

Union, A. (2014). Implementation Strategy and Roadmap to Achieve the 2025 Vision on CAADP. *Addis Ababa: African Union*. 32pp.

United Nations (2005). *Designing Household Survey Samples: Practical Guidelines*. United Nations, New York. 255pp.

Wandji, N. D., Pouomogne, V., Nyemeck, B. J. and Yossa, N. R. (2012). Farmer's Perception and Adoption of New Aquaculture Technologies in the Western Highlands of Cameroon. *Tropicultural,* 3: 180 – 184.

Waterer, D. (2003). Yields and economics of high tunnels for production of warm-season vegetable crops. *HortTechnology,* 13: 339–343.

Webster, T. J. (2003). *Managerial Economics; Theory and Practic*e. Elsevier, California USA. 755pp.

Wells, O. S. and Loy, J. B. (1993). Row covers and high tunnels enhance crop production in the North Eastern United States. *HortTechnology*, 3: 92–95.

Wondimagegn, M., Bekabil, F. and Jema, H. (2011). Pattern, Trend and Determinants of Crop Diversification: Empirical Evidence from Smallholders in Eastern Ethiopia. *Journal of Economics and Sustainable Development* 2(8): 78-89.

World Economic Forum (2016). Global Risks. Geneva: World economic forum. [http:// www.weforum.org/repo6.3.2rts/global-risks-report-2015] site visited on 15/12/2016.

Xaba, B. G. and Masuku, M. B. (2013). Factors affecting the productivity and profitability of vegetables production in Swaziland. *Journal of Agricultural Studies,* 1(2): 37-52.

APPENDICES

Appendix 1: Household Questionnaire

Background Information

Date: ____

Household No.:____

Enumerator's Name: ___________________________________

Respondent's Name_____________________________________

District: ____

Location: ____

Village: ____

Type of farmer (√)

1. Greenhouse tomato farmer (...) **2. Open-field tomato Farmer (...)**

Section A: General Information

A1. Which **year** did you **star**t tomato growing? **Year start1_______**

A2. When you **started,** what area did you have**? Ha start_______ Hectares**

A3. How many **Hectares** do you plant **now**? **Hectares now_______ Hectares**

A4. How do you compare your existing tomato **production** with that of **5** years ago? **(**√**)**

1. Increased 2. Decreased 3. No change 4. **N/A**

A5. If production has decreased what are the **reasons**? **(**√**)**

1. Pests and diseases 2. Shortage of land 3. Lack of rainfall 4. Shortage of input 5. Shortage of labour 6. Poor soil fertility 7. Reduced profitability 8. Other(Specify)____________

A6. What were the **highest** and the **lowest prices per quantity unit** for your tomatoes during the year?

1. High price (BWP)___________per_________________(Output unit)

2. Low price (BWP)___________per_________________(Output Unit)

A7. Which **months** do you record the **highest** and the **lowest** tomato prices?

1. Months high________________________________

2. Months low_________________________________

A8. What are the reasons for high prices?

____

____

A9. What are the reasons for low prices?____

____

A10. Do you obtain fair price for your tomatoes? (√)

1= Yes (...) 2= No (...)

A11. If **No',** what are the reasons? (√)

1= Poor quality of product (...) 2= Lack of transport facility (...) 3= Low local demand (...)

4= Inadequate market (...) 5= Over supply (...) 6= Others (Specify) _________ (...)

A12. Considering the last two years how has the price of your tomatoes behaved? **(√)**

1= Increased (...) 2= Decreased (...) 3= No change (...) 4= **N/A** (…)

A13. How do you rate the **performance** of your tomato enterprise? **(√)**

1= Very good profit (...) 2= Satisfactory profit (...) 3= little profit (...)

4= No profit (...) 5= Loss (...) 6= don‟t know (...)

A14. What is the type of the **main road** that you use to the market? **(√)**

1= Gravel (...) 2=Tarmac (...) 3= Dirt road (...)

A15. What is the **condition** of the road? **(√)**

1=Good (...) 2= Bad (...)

A16. What is your main **source** of water? **(√)**

1= Well (...) 2= Borehole (...) 3= River (...)

4= Other (specify) (...)_________________

A17 Land ownership and use details

A17.1 What is the size of your farm? ____________ Hectares

A 17.2 Landownership? **(√)**

1= Own (…) 2= Rented (…)

A17.3 What is the land tenure situation of your land? **(√)**

1= Has title deed (…) 2= Doesn’t have title deed (…)

A17.4 For how long have you been farming? ____________ Years)

A17.5 What is the size of land occupied by Tomatoes? ____________ hectares

A18. What is the land hiring rate per Hectare in this area? _____________Pula./Ha

NB 1. A19 – A26 applies only for High tunnel tomato farmers, else skip to A27. NB

2. A19 –A21 may be N/A if A1 –A3 already filled for greenhouse

A19. Which **year** did you **start greenhouse** tomato growing? **Yearstart2________**

A20. How many **units** did you start with**? Unit start ___________**units of_________M^2

A21. How many greenhouse **units** do you have now? **Unit now_______** units of______M^2

A22. How did you **acquire** your High Tunnel **technology**? **(√)**

1= Ministry of Agriculture (…) 2=Non-Governmental Organization (Specify) (…) _______ 3=Inputs supplier (specify) (…) ________ 4=Own initiative (…) 5= Other (Specify) (…) ____________

A23. What **type(s**) of tomato Tunnel(s) do you use? **(√)**

1= Rectangular (Gamble) (…) 2= Round roofed (Arched) (…) 3= Other (Specify) (...)

A24. What type of **plastic material cover** your tomato greenhouse? _________________

A 25. What are your main greenhouse **frame materials** made of? **(√)**

1= Metal pipes (...) 2= Timber (...) 3= Others (specify) (...)________________

A26. What is your **main water source** for your tomato **greenhouse**? **(√)**

1= Well (...) 2= Borehole (...) 3= River (...) 4= Other (specify) (...)_______________

A27 Non-tunnel adopters, provide information on knowledge about tunnels.

A27-1	Do you know high tunnel?		1= Yes 2= No
A27-2	If yes to A27-1 when did you first learn about tunnels?		………………….. year
A27-3	If yes to A27-1 from whom did you first learn about tunnel?		1= research/on farm trial 2=Extension agents 3=farmers' field day 4=other specify
A27-4	24. Have you ever participated in the high tunnel		1=Yes 2= No

	training/ demonstration?		
A27-5	If yes to A27-4 when was this?		………………year

A28. What are your **reasons** for **not adopting high tunnels for** tomatoes? **(√)**

1= Inadequate capital (…) 2= Inadequate knowledge (…) 3= Inadequate labour (…) 4= Poor prices (...) Not beneficial (…) 5= Inadequate water (…) 6= Inadequate market (...) 7= High production costs (...) 8= Low yields (...) 9= High Marketing costs (...) 10. Other (specify) (...)____

A29. Approximately how many kilometres is your tomato market from your farm? _____Kms

Section B: Household Demographic Information (household details)

B1. Please provide the following details as regards the **household members**

Household members	Number	Total number of household members
Number of working		
Number of Non-working		

B2. Please provide the following details as regards the household head

B2-1	**B2-2**	**B2-3**	**B2-4**	**B2-5**	**B2-6**	**B2-7**	**B2-8**
Gender of household head 1=Male 2=Female	Age *(See Age Codes below)*	Position of household head in household 1=Husband 2= Wife 3=Child 4=Other (Specify)___________	Number of months living at home in the last 12 months	Attained Education level 0= None 1= Primary 2=Secondary 3= Tertiary Education	Occupation of the household head *(See occupation Codes below*	If employed in **B1-6**, indicate number of months involved in the employment in the last 12 months	What was the monthly estimate of income from this occupation? (BWP)

Codes B2-2: 1= Below 20years 2= 20-30years 3= 30-40years 4= 40-50years 5=50-60years 6= 60-70years 7= Above 70 years

Codes B2-6: 1=Farming 2= Self-employed (outside the farm) 3=Casual labour 4= Formal Employment

5= Unemployed 6= Other (specify) _______

SECTION C. COSTS INFORMATION FOR TOMATO PRODUCTION

C1. Variable costs Please provide the following information for a **main** specified area**......................... (√) Hectares**

No.	**C1-1**		**C1-2**	**C1-3**	**C1-4**	**C1-5**	
	Variable costs Type.	Unit of measure for variable cost type	Price per specified unit (BWP)	Quantity used	Source of inputs *(See codes)*	Transport cost per unit of inputs (BWP) **(Instruction: fill for all inputs)**	Remarks (e.g. clarification of names of chemicals, number of times for activities, type of labour used etc)
1	Land rent (If rented)	Hectare					
2	Seeds	Kg					
3	Seedlings	Number					
4	Nursery management	Man-days					
5	Land preparation	Man-days					
6	Herbicides	Litres					
7	Planting	Man-days					
8	Disinfectants	Litres					
9	Insecticides	Litres					
10	Fungicides	Litres					
11	Water	Litres					
12	Training	Man-days					
13	Pruning	Man-days					
14	Weeding	Man-days					
15	Harvesting	Man-days					
16	Grading & sorting	Man-days					
17	Packing	Man-days					
18	Produce Transport						

Section D: Tomato Production

D1. Tomato Yield Levels Please indicate details on **your tomato production details** for the past year (2010- 2016).

D1-1		D1-2	D1-3	D1-4	D1-5	D1-6	D1-7	D1-8
Plot or unit size	Unit of **area**: Heactare	Variety (ies) grown	Quantity of **marketable** output produced	Quantity of **unmarketable** output produced	Output quantity units *(see codes below)*	Average Price per Quantity unit (BWP)	Total value i.e. D3*D6 (BWP)	Where sold *(see codes below)*
	Ha/m^2							

Note: Output should include what was sold, consumed at home and gifted out etc.

D1-5 Units codes: 1=Kg;   2= Large box (64kg); 3=Medium box (35kg); 4= Bucket (14kg); 5= Other (specify) _______

D1-8 Where sold codes: 1= Farm-gate 2= Retail shop 3= Traders 4= Contracted markets (Processing plant)

5= Whole sale markets (BHM) 6= Other (Specify) _______

D2-1. Have you signed contract with any buy

1. yes (…..)   2 No (……)

D2-1.1 if yes, for how many months or years…………………………..

D2-2 Approximately how many kilometres is your tomato market from your farm? _____Kms

D3. Machinery, equipments, structures etc used. Please provide the following details specifically for tomato production

D3-1	**D3-2**	**D3-3**	**D3-4**	**D3-5**	**D3-6**	**D3-7**
Item *(see codes below)*	Number	Year bought/ constructed	Initial cost (BWP)	Economic life (years)	Annual repairs, and maintenance cost (BWP)	Salvage value (BWP)

D3-1 Item codes: 1=Tunnel 2=water pump 3= car 4= Wheel barrow 5= Knapsack-Sprayer 6= Pruning knife 7= Protective clothing 9= Hoe 10= spade 11= Irrigation equipment 12= Watering can 13= Water tank 14=Well 17= Others (Specify) ___________________________

Section E: Access to Extension Services

Please provide the following information regarding any form of **extension services for tomato production** received over the last **12 months.**

Agent/source	**E1**	**E2**
	Did you receive any information from: 1=Yes 0=No	If **Yes in E1**, how many times were you visited?
Government agent		
Agricultural Research		
NGO		
Others(Specify)		

Section F: Credit Availability

F1. Did any household member **try to get any credit (cash or in kind)** in the 2010/2011 year? **(√)**

1=Yes (...) 0=No (...)

(If 'No' skip to F9)

F2. If „**Yes',** did you **receive** the **credit** that you tried to obtain? **(√)**

1= Yes (...) 0=No (...)

(If 'No' skip to F6)

F3. How **much credit** did you receive? BWP________

F4. Which were the **main sources** of credit and the **value** received from each? **(√)**

1= Family and friends (…) Value BWP. __________ 2= CEDA (specify) (…)

____

Value BWP.___________ 3= Commercial banks (…) Value BWP. ___________

4= Informal lending

Institutions (Specify) (…) _______________ Value BWP.____________

5= ISAAPD(…) Value BWP. ___________ 6= other (specify) (…)

_________________________________ Value BWP. ___________

F5. Did you experience any **difficulties** in getting the credit?

1=Yes (...) 0=No (...)

F6. If **'Yes'**,

what were these difficulties?

1……………………………………………………………..

2……………………………………………………………

F8. If you tried to get credit **but did not get** what was the **reason(s)** for not getting? **(√)**

1= No collateral (...) 2= Outstanding loan (...) 3= dont know (...) 4= No account (...) 5= Lender lacked cash (...) 6= It is still on process (…) 7. Other (specify) (…) ___________________

F9. If no one in the household tried to get credit, what was the reason(s)? **(√)**

1= No collateral (...) 2= Outstanding loan (...) 3= Not interested 4= others (…)__________

Section G: Labour Information

G1. What is your main source of labour? **(√)**

1=Family (...) 2=Permanent (...) 3= Hired/casual (...) 4=other (specify) (…)

____

G2. What is the average wage rate per man-day in this area? ______BWP /Md

G3. Are there times when you encounter any labour shortage in tomato production? **(√)**

1= Yes (...) 0= No (...)

G4. If **'Yes' in G3**, for what specific activities, have you encountered tomato production labour shortage? **(√)**

1= Cultivation of Land (...) 2= Planting (...) 3= Weeding (...) 4= spraying (...) 5= Pruning (...) 6= Training (...) 7= Others (Specify) ___________ (...)

G5. If **'Yes' in G3**, how do you overcome these problems posed by this labour shortage? **(√)**

1= Hiring labour (...) 2= Assistance from relatives (...) 3= Social assistance (...) 4= Was not able to overcome the problem (...) 5= Others (Specify) ____________

Section F. Group Membership

H1. Is anybody in the household a member of a group? **(√)**

1= Yes 0 = No

H2. If „**Yes'**, which type(s) of group? **(√)**

1. Self Help group (…) 2. Cooperative Society (…) 3. Welfare group (…) 4. Farmer Association (…) **5.** Other (Specify) (…) …………….

H3. If „ **Yes'**, how has the household member benefited from the group? **(√)**

1. Savings (...) 2. Loans/credit (…) 3. Crop and livestock sale (...) 4. Livestock farming (...)

5. Accessibility to safe water supply (...) 6. Merry go round (...) 7. Tree seedlings sale (...)

8. Improved crop production (...) 9. Other (specify) (...) ……………………

I3. Farm income

What is your estimated annual farm income? ____________BWP. Per year.

Thank You Very Much for Your participation and Cooperation!

Appendix 2: Net profit of tomato production under high tunnel and open field

	Type of farmer							
	High Tunnel				**Open-field**			
Variables	**Mean**	**Std. Dev**	**Min**	**Max**	**Mean**	**Std. Dev**	**Min**	**Max**
YieldPerHa	**83.95**	32.34	41.21	139.83	**15.46**	16.63	0.96	79.70
TRPerHa	**644803.94**	232866.72	337159.08	1016969.71	**107589.07**	115166.67	6000.00	583820.00
SeedCost	**24277.87**	8592.66	8250.00	38333.33	**5320.53**	3176.97	392.00	17850.00
ChemInput	**45025.01**	30857.43	19734.54	137743.33	**21413.50**	17462.92	2400.00	90804.20
FERTCost	**35594.71**	17006.09	17777.78	81670.75	**22103.42**	23472.51	2800.00	188960.00
EnergyCost/Ha	**7722.94**	4631.52	2625.00	20000.00	**11930.76**	7771.84	2690.00	30141.60
LabourCost/Ha	**1543.21**	2293.31	0.00	7916.67	**3481.92**	3897.83	0.00	25920.00
Transportcost	**2480.03**	714.16	1100.00	3600.00	**2816.82**	1549.67	800.00	6300.00
TVCPerHa	**117755.12**	51452.52	77906.63	254950.83	**67066.94**	38745.30	17348.32	205160.00
GMPerHa	**515524.19**	242168.98	200562.50	935835.17	**40522.12**	118691.81	-175240.00	524144.54
InsuranceCost	**15355.56**	10542.65	0.00	24600.00	**0.00**	0.00	0.00	0.00
LoanCost	**41925.73**	23141.97	0.00	78792.00	**1839.60**	6501.35	0.00	34392.00
AdmniCost	**609.74**	127.07	431.88	904.05	**640.45**	358.00	181.91	3122.40
Perm Labour	**42333.33**	18865.60	14400.00	109200.00	**9135.75**	19580.47	0.00	180000.00
Depreciation	**15562.49**	5704.80	4500.00	24300.00	**0.00**	0.00	0.00	0.00
Total Fixed Cost	**126740.22**	41516.09	40570.66	211344.95	**16433.41**	21128.56	3731.71	187163.09
Net Profit	**388783.97**	247533.78	35808.29	825508.67	**24088.72**	118929.44	-188562.40	512519.01