ASSESSING THE CURRENT STATUS OF GREENHOUSE INDUSTRY IN SELECTED REGIONS IN GHANA

BY

DAVID-ETTA MOORE COLEGUWOR

(10556927)

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE CROP SCIENCE DEGREE

DEPARTMENT OF CROP SCIENCE

SCHOOL OF AGRICULTURE

COLLEGE OF BASIC AND APPLIED SCIENCES

UNIVERSITY OF GHANA

LEGON

July, 2018

DECLARATION

I hereby declare that, apart from the references to the work of other researchers which have been appropriately cited, the outcome of this work is my own actual fact-finding and that this research has neither in entirely nor in parts been presented for another degree elsewhere.

……………………..

DAVIDETTA MOORE COLEGUWOR

Date….……………………..

(Student)

……………….. Date……………………..

PROF. GEORGE NKANSAH

(Supervisor)

……………….. Date…………………..

DR. ALFRED ASUMING BOAKYE

(Co-Supervisor)

DEDICATION

My Dad, Mr. David M. Moore and my Mother Mrs. Patty K. Moore are undoubtedly wonderful gift from the almighty God. Thank you, I am grateful for your continuous inspiration especially, as I was pursuing my studies.

My wonderful husband Mr. Yanquoi B. Coleguwor who stood by me until the end. My great daughters, Wenwu and Yanetta Coleguwor, who I denied sufficient motherly love at their tender ages, for the period I was away furthering my studies, yet they always welcomed me back with a pat on my back. You gave me a lot of motivational help and you are so very special to “Tata”.

To my lovely parents, beloved husband and my adorable daughters!

ACKNOWLEDGEMENT

It is my pleasure to express my gratitude to God Almighty for making it possible for me to complete this research work. Without the unreserved help, valuable guidance, corrections, patience and dedication offered by my supervisors, this study would not be achieved. I just won't forget their efforts soon. So my sincere and heart-felt thanks first go to Prof. George Nkansah and Dr. Alfred Asuming Boakye. I also express my sincere gratitude to various individuals (teaching and administrative staff) from the Crop Science Department, University of Ghana, for their generous support, guidance and encouragement throughout my entire Master of Science in Agricultural and Applied Horticulture Science course. I also thank the Borlaug Higher Education for Agricultural Research and Development (BHEARD) family, especially Karen Duca for the sponsorship and moral role played throughout my studies period. I indeed appreciate my colleagues, the Crop Science Masters of Agricultural and Applied Horticulture class, of the year 2017/19, University of Ghana, who were there for me whenever I needed help, and especially on technical pieces of advice. I thank them from the bottom of my heart. My profound gratitude goes to the institute of applied science and technology (IAST) for a meaningful contribution during the analysis exercise. My lots of other thanks go to the enumerators and the greenhouse vegetable producers for the input made during the data collection exercise. I also acknowledge all other individuals and members of my family for their moral, spiritual and financial supports during this study. Lastly, friends who made wonderful contribution directly and indirectly in bringing me this far are highly remembered and appreciated.

ABSTRACT

The greenhouse technology is a booming segment of agriculture in the world, because it offers a favorable climate conditions which increase plants growth as the plants are grown in a controlled environment.

This research assessed the present conditions of the Controlled Environment Agriculture (CEA) in Ghana and emphasized on issues that are paramount to Greenhouse vegetable production effectiveness. The general objective was to evaluate the current status for greenhouses in Ghana and provide recommendations that will lead to high productivity and profitability. The specific objectives for the study were to assess the current structures and equipment types used by greenhouse operators, determine the profitability in operating greenhouses in Ghana and assess commercialization channels, assess climate management practices of greenhouse farmers, evaluate the greenhouse agronomic practices in Ghana and provide recommendations on how greenhouse vegetable production could be improved. Primary data was collected through a field survey using structured interview questionnaires, while secondary data was gathered through literature review. Data collected from the 12 locations comprising 118 greenhouses in the 7 regions was analyzed using the Statistical Package for Social Science (SPSS) software. The profitability of operating greenhouses was determined using the Gross profit analysis.

The survey identified three types of greenhouses in Ghana – EnviroDome ventilation system, Dizengoff and the Malaysian type. It became obvious during the survey that amongst the three types, the EnviroDome ventilation greenhouse system for vegetable production is more profitable than the other two. Its advantage over the two is that it has special in-built features which provide the requisite micro-climatic conditions necessary for plant growth and climatic data management in greenhouses for easy adoption by stakeholders. The yield, price and variable costs were based on producer's responses for the 2017/2018 production season. Cost materials of vegetable production was put into variable costs, and fixed costs. Variable cost was all inputs and labour costs that were directly related to vegetable production like seeds, substrate, agro-chemicals, disinfectants, water, trellising ropes, electricity, fuel, transport, investment, among many others.

The study also analysed the socio-economic characteristics of the current status of greenhouse vegetable production in Ghana. Climatic conditions, management practices, equipment, production system and the profitability of greenhouses vegetable production in seven (7) regions in Ghana were some key factors considered. The socio-economic characteristics were analysed using percentages and ranked with the aid of SPSS software. The study used Gross Profit analysis to determine and compare the profitability of different types of greenhouses production systems identified in Ghana.

As part of greenhouse recommendations, the study identified the need to promote good agricultural practices within the vegetable sector in the country. Therefore, there is the need for government to actively participate in promoting and supporting commercial vegetable sector to have all the acceptable standards which are needed for safe and healthy vegetable production. It is also essential for the Ministry of Food and Agriculture to partner with universities, research institutions and developing partners to train growers and extension agents.

Table of Contents

LIST OF TABLES

LIST OF PLATES

LIST OF ACRONYMS AND ABREVIATIONS

CEA	Controlled Environment Agriculture
CSIR	Council for Scientific and Industrial Research
^oC	Degree Celsius
et al.,	and others
FOHCREC	Forest and Horticultural Crops Research Centre
HIGH-TECH	High technology
IPM	Integrated Pest Management
LOW-TECH	Low technology
MEDIUM-TECH	Medium technology
pH	Power of hydrogen
PAR	Photo synthetically active radiation
SPSS	Statistical Package for Social Sciences
SEE	South East European
TC	Total Cost
TR	Total Revenue
LCD	Liquid-crystal display

DEFINITION OF KEY WORDS

Greenhouse vegetables farmer: Someone who grows vegetables under controlled environment (Liu *et al.*, 2005).

Gross margin: Is the difference between gross revenue and variable costs (FAO, 1985).
Profitability: Is the ability of an enterprise or a project to make profit.

Market: In this study, the market is the nearest marketing canter where vegetables farmers take their produce for sale.

Revenue: Earnings

CHAPTER ONE

INTRODUCTION

1.1 Brief overview of Agriculture in Ghana

Farming remains of great importance to the economy of Ghana and accounted for about 19% of Gross Domestic Product (G.D.P) in 2017, approximately 60% is employed as a labour force of the Ghana Statistical Service (GSS) (Ghana Statistical Service, 2018). Despite its overall economic importance, it is characterized by subsistence and small holder farmers who consider Agriculture as a way of life and not only as a commercial enterprise. Therefore, very little modern commercial farming has been introduced and, thus, the full potential of agriculture has not yet been exploited. Under these circumstances, national food security is unfortunately not achievable.

Ghanaian farmers traditionally rely on rain fed cultivation to grow their crops while saving up their own seeds and generally use such poor quality seeds for propagation. This has led to the misuse of both water and fertilizers giving the farmer no control over their likely yields, often resulting in either a poor or bumper harvest of short shelf life produce, neither of which are beneficial to the farmers or the consumers.

For Ghana to achieve national food security therefore and make meaningful inroads into the global export markets, farmers must rapidly learn to make optimum use of their natural resources in order to grow better quality product with much higher yields. This can only be accomplished if farmers have access to modern low cost technology with technical know-how and are taught how to use them, thereby enabling farmers to provide sufficient food for the nation, rise above the level of subsistence farming and become an integral part of a middle income economy. Thereafter, agriculture will become the sector of choice for employment and investment (David Jackson 2014, Personal correspondence).

The Ghana Government accepts the premise that national food security can only be realised through the wide-scale introduction of modern commercial agriculture and that such modernisation will spearhead the development of the economy (World Development Report, 2008).

1.2 Background information of greenhouse

The production of plants has turned into both art and science work in the world. Around 95 percent of the plants is being produced in an open farm land field. Humans have learned how to grow crops under natural environment conditions back since creation. Under an unpleasant climate conditions where plant cannot be grown, a system of growing crops under a controlled environment that offers high value plants has been developed. The method is a continuous process which provides for the crops a protection from the excessive cold and other adverse conditions (biotic and abiotic) which is referred to as Greenhouse technology. The structure is normally protected with unique covering materials. It contains walls and roof which is made with a transparent materials such as plastic and glass in which plants will require a regulated climate conditions during production.

Modern greenhouse system or protected Agriculture environment sometimes known as controlled Environment Agriculture (CEA) may be explained as; Integrated Science and Engineering-based technology approach to begin establishing a suitable environmental conditions for plant production while advancing the usages of resources including water, energy, space, capital and labour thereby, providing desirable product and biological processes under controlled environment conditions (Shakuntala and Anil, 2015).

The technology has been instrumental in improving the production of horticultural crops such as tomatoes, cucumber, sweet pepper, hot pepper and lettuce and water melon in the world. The primary reasons for protected cultivation in the tropics are for pests and diseases exclusion, protection from extreme solar radiation, increased yield and an all year round production that offers scarcity in the dry season. It also provides optimum growing environment with the ability to achieve better quality and healthier crops by maximizing the production area than the open field production. This is mainly done through the enclosed structure and protective antiviral netting which protects crops from unfavorable climate conditions such as; heavy rain, wind, cold, precipitation, excessive temperature, and other harsh elements (Reddy, 2015).

The usage of loop drip irrigation system and the proper application of fertilizers that guarantee quality crop nutrition and increase the production capacity to bear more is also a cardinal point to greenhouse production. Creating an ideal micro climate around the plants is essential. This process works by building a greenhouse where the environmental conditions are so modified that one can grow crops out of season and in any place by providing conducive environment with a reduced labor force (Kropff, 2011).

The technology also involves control use of agro-chemicals in controlling pests and diseases. The economic life of the structure is estimated to be about (30 years), greenhouse has been making investment in it worthwhile due to significantly higher yields compared to open-field cultivation. (Clive and John, 1997).

In the tropics, plants in open-fields cultivation are often destroyed by severe storms and suffer from many pests and disease. Under these circumstances, although plants can be highly productive, their fruits are generally not of the highest quality or, they may contain too many residues of plant protection chemicals. This is unfortunate, given the tropical areas more than enough available sunlight and, very often also, more than enough water (Joachim *et al.*, 2013, 2014).

In Ghana, the greenhouse technology was introduced by Prof. George Oduro Nkansah in 1996 and has been gaining ground rapidly. With the adoption of this technology in Ghana, tomato yields have increased from the national average of 7.5 tons/ha to 200tons/ha (Nkansah, unpublished, 2018).

The greenhouse technology can ensure food security in Ghana. It is also seen as a good way to get youth involved with agricultural activities in increasing productivity in the greenhouse.

In Ghana, were contracted by GhanaVeg to carry out a survey on the status of greenhouses in three regions in Ghana. They recommended that, periodically and with the introduction of more greenhouses, the greenhouse structures, the types of vegetables being grown, the equipment used as well as the climatic conditions and agronomic practices must be evaluated or assessed. Further recommendation was also made to extend the research to other regions in Ghana and update the information obtained in the earlier research. They again recommended that, the problems of low productivity are unacceptable standard equipment, inadequate information regarding the equipment present that a greenhouse should have and inadequacy of well-trained management staff to consequently train farmers should be looked at. The low adoption of greenhouse vegetable production system has also been observed even though the system can be profitable (Elings *et al*., 2015).

It is in this light of the above recommendation and challenges that this research was deemed necessary to assess current status for greenhouses industry in 7 regions of Ghana and provide recommendations for good conditions in improving growth, yield and quality of vegetables in the country as well as recommend appropriate design or structures and technology for increased adoption and profitability.

1.3. Study objective

The general objective was to assess the current status of greenhouse industry in selected regions in Ghana. The specific objectives were aimed to:

- Assess the current structures and equipment used by greenhouse operators.
- Determine the profitability in operating greenhouses in Ghana and assess commercialization channels.
- Assess climate management practices of greenhouse farmers
- Evaluate the agronomic practices of greenhouses in Ghana.
- To provide recommendations on how greenhouse vegetables production can be improved in Ghana.

1.4. Scope and limitations

This survey covered 7 regions out of the 10 regions of Ghana. This is mainly due to the non-existence of greenhouses in the rest of the other three regions. The study targeted current status of greenhouses technology in Ghana. The selected key issues in this study were, socio-economic characteristics of greenhouses, challenges influencing farming in the controlled environment production system and a determination of profitability of greenhouses in different locations within the 7 regions. It also assessed agronomic practices and standard equipment being used in the greenhouses for higher productivity. Data collected was mainly from managers and owners through the means of administered questionnaires. Data limitation included the inability of managers of some greenhouses to provide information on costs and sizes of their greenhouses because such information was considered classified by the owners of such greenhouses.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of greenhouse crop cultivation

The use of greenhouse technology or Controlled Environment Agriculture started in the year 600BC to date. Although the environmentally controlled technology has been in existence since the roman times, the adapted concept later emerged in Netherlands and England in the 17th Century. In the 1800s, Charles Lucien Bonaparte, a French botanist who constructed the first practical modern greenhouse in Leiden and Holland, installed it for the sole purpose of growing medicinal tropical plants and has ever since been accredited with such title. Today, the technology has also included the growing of horticultural plants worldwide (Bowery Farming**,** 2017).

The technology covers 130 countries in the world which are commercially involved into vegetable production with the total area estimated of 497,815 hectares under a protected cultivation. Hydroponic or soilless greenhouse system accounts for about 100,000 hectares of the total world area than the other systems (Hickman, 2018).

Turkey has been recognized as one of the leading greenhouse producing countries in the world. In Turkey, with the greenhouse technology, it is known that vegetable production is on the highest increase and can be accounted for about 95% of the total area, flower production is 4% followed by 1% of fruit production. Major strength of a successful greenhouse vegetable production in the country has relied on using materials made of glass and geothermal resources that are used for keeping the greenhouse warm among many others.

Turkey's total protected cultivated area covers about 66.362 hectares with 38.943 hectares of modern structures and 27.422 hectares of glass and plastic structures.

Greenhouse technology adoption defers in various location depending on the climate conditions and socio-economic environment. The Controlled environment technology originated in northern Europe, and experiences their speedily and actively stimulated development in other locations, including the Mediterranean, North America, Oceania, Asia and Africa. Protected farming in South East European countries still remains a period of transition following a decline in importance wake of social changes in the 1990s. Currently, the total controlled environment areas in South East Europe countries is about 104 560 ha, accounting for approximately 5.31 percent of total vegetable cultivated land. Wide areas of greenhouses cover low tech and are protected with plastic (Baudoin *et al.,* 2017).

Elings*, et al.* (2015; 2016) stated that successful greenhouse cultivation requires a combination of a good design, quality inputs, and adequate crop management including production planning, which can result in increased productivity. There is potentially a quick growing crop rate with higher yields and better quality; crop growth can be manipulated as well. Also, the use of agro-chemicals (fertilizers and pesticides) can be more easily monitored and controlled and, problems, such as, "run-off" can be reduced. In the light of this, Controlled Environment Agriculture a system which brings about attractive returns on investment opportunities, possibilities for environmental conversation is also provided (Elings*, et al*., 2015; 2016).

It should be of high significance to select an appropriate placement during the construction of the greenhouse. The structure must not be built close to a manufacturing area and not where too many people live. Flat land or even surface area is the preferred land for the construction which enables light level to be evenly distributed to the pants. If for any reasons the greenhouse is built on a land slanting up or down, it is necessary to prevent the structure from the problem of surface run-off. A good erosion control to the lower land is important everywhere around the site to avoid damages.

H2O and power source must be accessible to the location selected for the construction of the greenhouse.

Different techniques protecting the greenhouse production are possible anywhere. Producers can embrace and adapt to the technology in accordance with the climate conditions and particular crop requirements. High-tech greenhouse allows the control of climate requirement and an open range of plants growth manipulation which involves; shading/cooling by means of fogging, heating, dehumidification and artificial illumination. High- tech greenhouse produces high yields but have high initial costs attached. Naturally ventilated plastic tunnels and greenhouse are of low-cost alternative suitable for growers with small money or in regions with fluctuating demand (Naved and Balraj, 2012).

2.2 Types of Greenhouse

Basically, there are three types of Greenhouses: The high level of technology which is the most advanced technology, the medium level of technology and the low level of technology.

Low-Tech Greenhouse

Low-technology greenhouses are characterized by no, or minimal adjustments of the greenhouse environment. Greenhouse environment is dependent on outside, have passive ventilation (roof and side wall vents), no chillers, substrate is soil and is low cost ($25-30/m2) and yield (10-20kg/m2).

Low-tech structures are easily constructed, highly affordable and less automated requirement for significant producers. Whilst this type of greenhouse has edge over open-field farming, plant quality is still low due to substandard growing areas and high pests and diseases outbreak which can result into low yield during production.

Therefore, plants will need much effort in times of controlling the environment (Department of Primary Industries, 2018).

Medium-Tech Greenhouse

The medium-technology is a combination of the low and medium level technologies. The medium one has active and passive cooling systems with or without chillers and fans. It has simple environmental monitors and controls. They also have screened/shade greenhouse/High tunnels. Substrates used can be soil or soilless and cost ranges from $30-50/m2 with a range of yield: 20-50kg/m2. Growers need training to handle such systems.

The gutter height of the medium-tech greenhouse structure is lower than four meters and below 5.5 meters is the entire height. It also brings about more chances to deploy a powerful chemical-free to eliminate pests and diseases in the houses.

High-Tech Greenhouse

The high-technology greenhouse is a plant-response based environmental control that optimizes plant growth and maximizes productivity and fruit quality. It is a closed recirculating fertigation and hydroponic system with a computerized climate control of greenhouse (temperature, irrigation, shading based on integrated light, CO2 enrichment). It is closely and it ranges from $100-200/m2 and has a 365-day production cycle. Yield in this environment ranges from 75kg/m2 or 500t/ha/year and new crop can start when a finishing crop is ending. Research and teaching and training are carried out in this system and for commercial production.

There are also more chances to deploy appropriate integrated pests management measures that would provide a considerable higher yield per unit. Even though advanced agronomic practices are practiced in high-tech greenhouses, there is still a need to extend the High-tech greenhouse to other small producers (Lecture presented by Prof. G. O. Nkansah, 2017).

2.3 Greenhouse covering materials

The covering of the greenhouse structure is what transforms it from the frame to the environment that makes it able to support controlled crop production and capable of achieving the desired greenhouse effect. The covering influences the characteristics of the micro-climate provided by the greenhouse. The right choice must be with the appropriate covering materials that will have positive impact on these quality features which are of greater concern of providing energy to the plants, wide-spread of light, quantity of shading that is needed and the suitable average of temperature and relative humidity. The choice should also focus on the type that is long-lasting.

Among these materials the most common ones are the flexible plastic film, the frequently utilize type is the **polyethylene** and the rigid kind like; plates of polycarbonate or glass.

The strong plasticity of the polyethylene is the most essential aspect it has and makes simple to install. It is also easy to handle and in affordable prices.

The **plate's polycarbonate** material gives a long duration and protects the structure from smashes. This material is mostly used in areas with high climate conditions with extreme level of rain, snow, ice, sleet and etc. Its unfavourable circumstance is the high cost that is associated with it than the polyethylene ones.

The glass materials are utilized during the cold climate season. It conserves enough of water and need an advance skill to install it than the simple plastic types. It is also highly expensive as compared it to others. This material is heavy in weight, difficult to carry and very weak in reacting to damages to the greenhouse structures (Huete, 2018).

2.4 EnviroDome greenhouse and its specifications

EnviroDome Greenhouse Technology system is a new system of greenhouse used in the production of various types of vegetable crops in the country which started in 2013. It is a new system which comes with so many in-built features such as: Height of 5 meters, Loop irrigation system and Chimney for lowering the heat inside the greenhouse among many others specifically designed for climates in Ghana and tropical Africa, and specifications unavailable in ordinary greenhouse which was already in the country before the introduction of the EnviroDome ventilation Greenhouse Technology. This technology has properties for light transmission, insect protection nets, loop gravity drip irrigation system, thermal screening and ventilation systems using special chimneys and can be manually operated. The EnviroDome ventilation greenhouse systems will ensure an all-year-round environmental controlled agriculture production through transformation of the mode of farming. EnvironDome ventilation Increases the yields of farmers which can assist meeting the health, nutritional and food security needs of the nation. Moreover, the produce will meet international market specifications. Increased productivity of farmers will also increase their disposable income. In many developing countries, there is a need to exist for a low-cost greenhouse using locally available materials where possible (Hickman, 2010).

2.5 Increment in productivity and yield

In the last 20 years, in Mediterranean climate countries, the competitions amongst greenhouse growers have significantly increased. There has been an uprising situation in managing the surroundings of the technology as it relates to the scheme, kind and standard of the protected plastic materials during this time. Significant improvement has also been made in properly managing fertigation, mulching, hybrids which produce high yield and panting materials such as cultivar and etc., plant training and pruning techniques, integrated pest management, climate control, soil solarization etc. At the effect, tomato greenhouse yield has resulted in 100 tons per hectare which was evaluated and reported as an excellence achievement in few years back. Additionally, 300 tons per hectare has begun a regular quantity of harvest for the growers in Mediterranean climate greenhouses. And also, the intensification of greenhouse crop production has produced improved growing climate conditions as a means of destroying so many pests and diseases. In 1993, the Regional Working Group on Greenhouse Crops in the Mediterranean area promoted by the FAO's Plant Production and Protection Division supported training research and development initiatives to upgrade the quality of national capacities which can revamp the greenhouse crop sector in Mediterranean environment (Papasolomontos *et al.*, 2013).

In Ghana, work developed at the University of Ghana Forest and Horticulture crops Research Centre at okumaning camp/Kade, Ashiaman (Unique Organic vegetables Farms) and Dawhenya National Entrepreneur Investment Plan Greenhouse project indicate yields of 150-220tons/ha. (Nkansah, 2016-2017 Unpublished Report).

2.6 Challenges affecting greenhouse production

There are some challenges facing production of vegetables in greenhouse in tropical zone today leading to low yield and abandoned greenhouses in the country. These are:

1. High average Relative Humidity and Ambient Temperature more than 40^0C
2. Reducing light below minimum threshold level in cloudy or rainy days.
3. Impedance of flower fertilization and fruit-set and development.
4. Low level of maintenance of exterior parts of the greenhouse structure.

5 Lack of adequate maintenance of undesirable vegetation, drainage and other environmental

elements surrounding the structure.

6. Lack of guttering causing algal growth on the outer surface of the cover material.

7. Poor quality orientation and improper site selection for the structure leading to incorrect direction of air flow, obstruction of winds and adequate solar radiate (Lecture presented by Prof. G. O. Nkansah, 2017).

2.7 Hydroponic Culture System in the greenhouse

Hydroponic culture of the controlled environment technology system involves the growing of vegetables in gravel, sand or artificial soil-less of mixture in tubs, bags, tubes, tanks, or troughs designed to allow the movement of nutrient media needed for plant growth. Although present automation systems can minimize fertilization and irrigation, labor, inputs, continuous monitoring of the system is very important.

Merits of hydroponics are: No soil is needed, the water stays in the system and can be reused- thus, lower water costs, it is possible to control the nutrition levels in their entirety thus, lower nutrition costs, no nutrition pollution is released into the environment because of the controlled system, stable and high yields and pests and diseases are easier to get rid of than in soil because of the container's mobility.

Demerits of this system also include: its environmental condition such as; presence of Fertilizer and High Humidity that provides suitable surrounding for high growth. The system can also be more susceptible to pathogen attacks like damp-off because of Verticillium wilt which is causing extreme water level connected to hydroponics (Maboko *et al*., 2011).

2.7 The standard equipment used in the greenhouse

For a successful vegetables and fruits growing using the greenhouse technology systems the producer has to take into account or consider the monitoring of growing factors such as the plant growing environment and the environmental factor during the production in the greenhouse. These factors are very important and critical for a successful profitable greenhouse enterprise.

As a result of technological advancement, instruments are now available for measuring the two factors. They are further grouped into two – the ones which measure environmental conditions including light, carbon dioxide (CO_2), temperature and relative humidity (RH) and, the ones which measure soil pH, soil moisture and fertilizer parameters of soil pH and electrical conductivity (EC) and magnifying lenses.

For the purpose of this study it is essential and necessary to briefly discuss only the important ones which can be used for a profitable enterprise like greenhouse production.

E.C meter

The electrical conductivity (EC) meter is used for measuring the actual amount of fertilizers mineral salt in a solution, and leachates.

pH meter is used for measuring the level of acidity of the growing medium or a fertilizer solution. The right pH level in a growing media is necessary when nutrients are available in plant uptake and absorption.

Thermometer

Thermometer is the most useful equipment for protected agriculture which takes records for not only the current temperature, but also the lowest and highest temperatures that occurs since the last time the thermometer was reset. Producers may observe and record temperature for every 24-hour period to see whether the thermometer is reset each day. While air temperature is the most common measured unit, soil and leaf temperature are more of an importance to plant production. When monitoring temperature, it is paramount to appropriately shade thermometers to prevent inaccurate readings due to heat load from light on the thermometer or on nearby materials, which can result into biased temperature readings (Ana, 2017).

Light meters

The intensity of light is measured by the light meter. Frequent reading the average of light intensity can help the growers to know when cleaning is necessary for the surface of the greenhouse. It also detects when to apply or remove shading component or shade cloth for excellence performance of the crop (Christopher *et al.*, 2018).

Magnifying lenses

Pest and disease symptoms are monitored and identified by a tool called Magnifying lenses. Technological advancement has led to one or few instruments capable of measuring several parameters. Data logger functioning as a single instrument is used for measuring the environmental parameters (Keron, 2013).

CHARPTER THREE

MATERIALS AND METHOD

3.1 RESEARCH QUESTIONS

1. What models and designs of greenhouses are being used in Ghana?

2. What is the economic performance of greenhouses in Ghana?

3. What are the management practices employed at these greenhouses?

4. What are the challenges facing greenhouses in Ghana?

3.2 Area of Study

The study was conducted in 12 locations in 7 regions of Ghana: Greater Accra, Eastern, Brong Ahafo, Ashanti, Volta, Northern and Central regions. The sample size was two (2) greenhouse locations per region. However, only one greenhouse was in operation in each of the Volta and Northern Regions. Sample size was therefore reduced from fourteen (14) to twelve (12).

3.3 Sampling Design/Questionnaire

The study utilised a cross-sectional survey conducted on the status of Greenhouses in Ghana. The first stage was a purposive sampling technique to select the area of study which has a greenhouse production growing area in the country, high potential for vegetables growing and it is strategically located relative to major vegetables market out-lets.

3.4 Data Collection

Information on secondary data was collected through literature review. Other sources included information provided by the Crop Services Directorate of Ministry of Food and Agriculture (MOFA).

The primary data information that was collected on socio-economic characteristics of vegetable farmers, climate management and profitability income were gathered by the use of structured questionnaire administered and also provided sources of variables for the analysis (Appendix 1). The scheduled interview was administered by the researcher and enumerators after a pretesting exercise at Somanya (in the Eastern Region of Ghana) with a greenhouse producer. During the piloting period, additional information provided through an informal discussion was of great help to revamp the questionnaire for the main survey. Major respondents included only managers and owners of the greenhouses. The areas covered by the questionnaire during the survey were:

- Basic information
- Production system
- Output Marketing
- Off gate and farm gate prices per growing season
- Input accessibility
- Price and profitability
- The climate data management in the greenhouse
- Challenges faced in the greenhouse production
- Agronomic and management practices used
- Nutrient fertigation type

3.5 Data analysis

Data was analysed using percentages and ranking which was aided by the Statistical Package for Social Sciences (SPSS) software.

3.6 Itinerary for the survey

	REGION	COMMUNITY	TIME OF VISIT
1	Volta	Vume	18th April, 2018
2	Eastern	Kade-Okumaning Camp	20th April, 2018
		Brekuso	25th April, 2018
3	Greater Accra	Dahwenya	27th April, 2018
		Ashiaman	2nd May, 2018
4	Central	Budu-Atta	4th May, 2018
		Tormefa	7th May, 2018
5	Ashanti	Kwadaso	4th June,2018
		Akomadan	5th June,2018
6	Brong-Ahafo	Odumase-Adoe	7th June,2018
		Techiman	8th June,2018
7	North	Kubenya Dungu- Tamale	13th June,2018

3.7 Locations with their various coordinates

	COMMUNITY	LATITUDE	LONGITUDE
1	Vume	6.007	0.551
2	Kade-Okumaning Camp	0.650	0.500
3	Brekuso	0.545	0.130
4	Dahwenya	5.7817	0.0386
5	Ashiaman	5.6786	0.0472
6	Kwadaso	6.420	1.390
7	Kubenya-Dungu Tamale	9.432919	0.8484 52
8	Budu Atta	5.3000	00.35.00
9	Tormefa	7.9528	1.0307
10	Akomadan	7.3960	1.9539
11	OdumaseAdoe	7.220	2.190
12	Techiman	0.003	2.733

Source: Survey results

3.8 The map of Ghana showing communities and regions visited during the survey

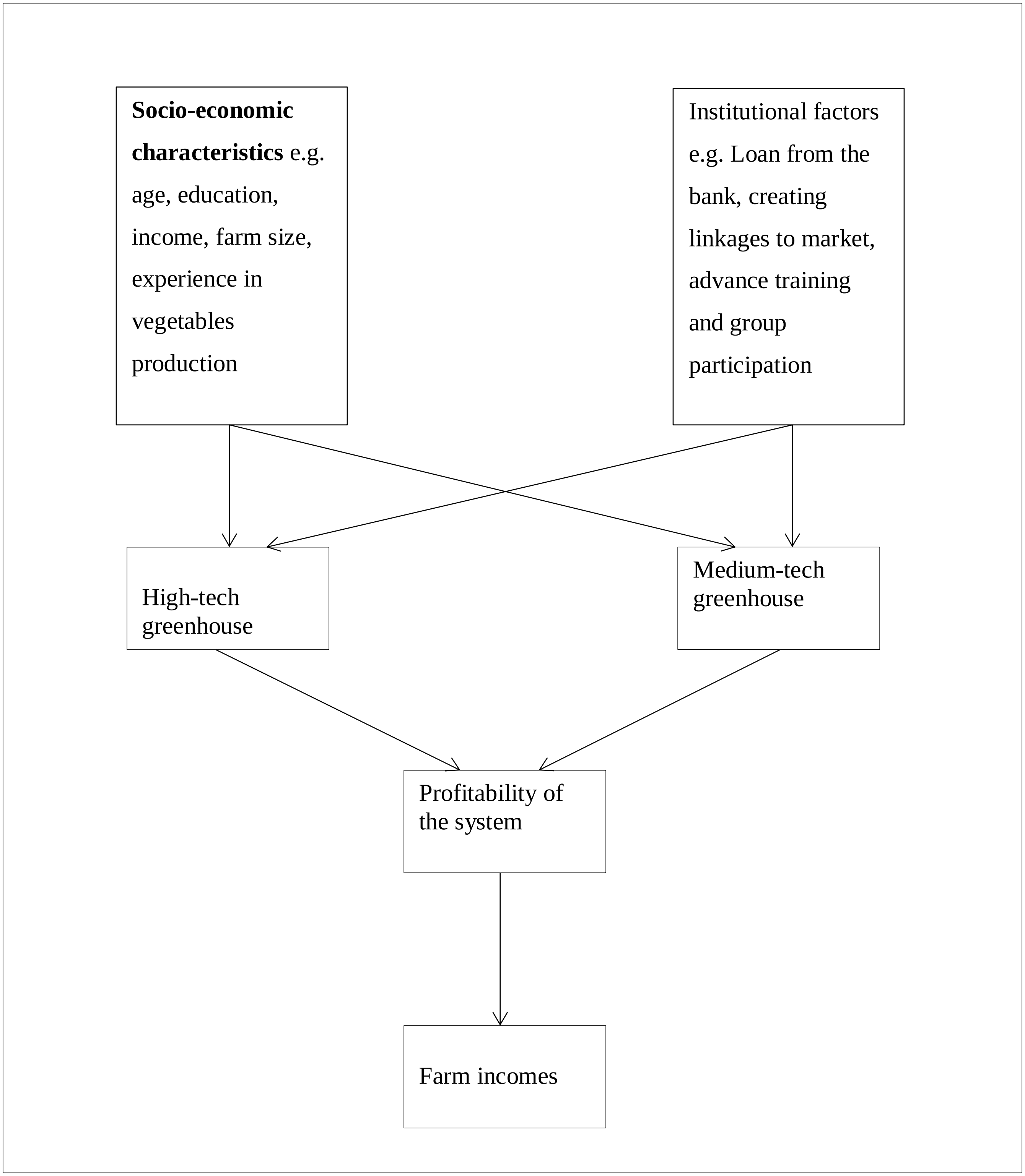
Source: survey directions and results

3.9 Conceptual Framework

The producers of a vegetable greenhouse can decide whether to use the high-tech, medium-tech or the low-tech greenhouse technology depending on his skills of managing the type of structure chosen. The decision could take into consideration the socio-economic characteristics such as; age, education, income, greenhouse size, the number of greenhouses and experience in vegetable production among many other factors. However, institutional and non-governmental organization factors will also influence the choice of type of greenhouse for production, for example; taking loan from the bank, creating linkages to market, advance training for producers on how to appropriately operate the greenhouse and group participation among others. After choosing high, medium or low technology greenhouse production system (assumed to have different profitability levels), given a producer's socio-economic characteristics and institutional factors, costs and returns may come at different levels. A rational farmer seeking to maximize profit will definitely choose the high-tech technology system with higher profit, the system that gives the highest yield account resulting in higher profitability. Plate: 1. shows the socio-economic and institutional characteristics of producers having great effect on only the high-tech and medium-tech greenhouses technology system. The second choice in this case could be both high-tech or medium-tech greenhouse system and it is assumed that alternative chosen is the one with highest profit in order to maximize income.

The low-tech is always preferred by small holder farmers and by growers in private's homes since the cost of production is significantly low and would not provide high productivity

Plate 1: Factors influencing vegetable production



3.9 Profitability and Economic Analysis (Production cost and income).

Discussions in this topic cover the first, second and third objectives of this study. It begins with the equation for estimating the gross profit of greenhouse which is equal to: (profit =Revenue-Expenses). GP analysis was conducted using SPSS software. Revenue and cost data were collected for the 12 communities. The yield, price and variable costs were based on producer's responses for the 2017/2018 production season. Various cost materials for vegetable production were categorized into variable costs, and fixed costs. The variable costs are all inputs and labour costs that are directly related to vegetable production like seeds, substrate, agro-chemicals, disinfectants, water, trellising ropes, electricity, fuel, transport, investment, among many others. Variable costs were calculated by using marketing product prices and the cost of labour.

Fixed costs are cost that does not change during any form of farming production and they include administrative salary etc. (Catherine & Jerry 2015).

Administrative costs can be estimated as 2–7 % of total gross production value or 3–7 % of total costs (Sait and Yuksel, 2006).

The total revenue was estimated by multiplying the estimated yield by the average price of the produce. The gross margin was estimated by subtracting total variable costs from the total revenue. (Kristin, 2014).

CHARPTER FOUR

RESULTS AND DISCUSSION

4.1 Socio-economic Characteristics of Greenhouse Growers: Age respondents

Based on the survey, the highest age categories for greenhouse producers were 31-40, 41-50 and 60+ years (Table 1). This means that, greenhouse producers interviewed during the survey were predominantly middle-aged farmers. The results show that majority (25.0%) of the greenhouse producers were in the age bracket of 31-60 years while the least (8.3%) were in the age bracket of 21-30 years. For the rest of the vegetable growers, 8.0% were in the 51-59 years age bracket. All of the 12 vegetable producer's respondents' educational level was tertiary. 25% were civil servants with other occupations at the same time involved with greenhouse production whilst the rest (75%) is only focused on greenhouse production. The greenhouse producers had a mean experience of 10 farming years with the lowest and highest experiences being 1 and 40 farming years, respectively.

Table 1: Age distribution of respondents

Age	**Frequency**	**Percentage**
21 – 30	1	8.3
31 – 40	3	25.0
41 – 50	3	25.0
51 – 60	1	8.3
60+	4	33.3
Total	**12**	**100.0**

Source: Survey results

Table 2: Education and other occupation of respondents

EDUCATIONAL LEVEL	FREQUENCY	PERCENTAGE
Primary	-	-
Secondary	-	-
Tertiary	12	100.0
Total		100.0
OTHER OCCUPATIONS		
Civil servants	3	25.0
Farmers	9	75.0
Total	12	100.0

Source: Survey results

4.2 Economic performance of greenhouses survey

Results that are shown in Table 4 indicate the highest and lowest annual production and income of greenhouse vegetable growers. The yield, revenue and profit are based on three growing circles per year. Profitability gives greater returns to producers and improves their livelihoods which is mostly seen as an achievable business.

The cost of production, income cost of agrochemicals and labour included the farm manager's sales. The income observed was by subtracting the production cost from the revenue generated.

The growers with more number of greenhouses and higher prices per kilo are likely to make more money which makes the business profitable. Those using high-tech system are also likely to get more money than those using low-tech greenhouse systems. Income for automated and EnviroDome ventilation greenhouse system were higher than the others and respondents agreed that the EnviroDome system is more suitable to grow vegetables.

Another observation that could bring about high productivity, high yield and income, and an improved production system in the 12 communities surveyed in Ghana is the need to establish inputs and output supply and buying linkages with customers. This arrangement may have positivity associated with it such as: timely and quality supply of inputs and fair price that would be provided by customers. This could be a serious weakness in the greenhouse production system, however, the survey results indicated that 50% out of 100% are involved in such practices shown in Table: 3. During the survey, light meter which is classified as one of the paramount equipment used in greenhouses was assessed to see whether it is available in the Ghanaian greenhouses. In light of the above, results that are showing in Table 3., Proves that, 25% of Light meter, 33.4% of Thermohygrometer, weighing scale 91.7% alongside with Drip irrigation system which produced 58.3% and fertigation tank of 50% were identified in the 12 greenhouses vegetable production in Ghana. Additional explanation is, not every greenhouse surveyed was found using all five of the equipment described due to the lack of finance to purchase and advance skills to properly manage them or, and lack of knowledge to operate the equipment at all.

The fourth objective of the study was achieved by evaluating the agronomic practices that are carried out in the greenhouse production system. It was found that, not much good agricultural/agronomic practices were carried out. Twenty percent of the respondents however practiced good agronomic systems. This may result in poor product quality and yield and lead to low income as well.

During the study, it was revealed that the greenhouse technology systems being used at Forest Horticultural Crops Research Centre (FOHCREC), Kade and the one at Techiman were primarily established for research and development purposes. The produce from both Kade and Techiman were not sold to the public, however, vegetables produced at FOHCREC were occasionally sold. The survey showed that, out of the two stations, only Kade does trainings, both theoretical and hands-on for students, agricultural officers, farmers and potential greenhouse farmers. It is therefore often referred to as a Centre of Excellence.

Table: 3 Standard equipment used in the greenhouse

Equipment	**Frequency**	**% of respondents**
LIGHT METERS	3	25.0
THERMOHYGROMETERS	4	33.3
WEIGHING SCALES	11	91.7
DRIP IRRIGATION SYSTE	7	58.3
FERTIGATION TANK	6	50.0
INPUT LINKAGES		
YES	6	50.0
NO	6	50.0
TOTAL	**12**	**100**

Sources: Survey results

Table 4: Production cost and income of greenhouses on annual basis

TOMATO PRODUCTION COST, REVENUE GENERATED AND GROSS PROFIT								
Regions/Locations	Cost of Production And Labour	Yield Per 270m^2	Price Per Kg	Revenue	Income (Profit)		No. of greenhouses per location	Types of greenhouse
Accra								
Ashaiman	20,400	7,500	10	75,000	44,600		13	EnviroDome
Dawhenya	20,000	6,600	8	52,800	32,800		25	EnviroDome
Ashanti								
Akumadan	29,000	6,000	7	42,000	25,000		2	EnviroDome
Kwadaso	30,900	7,500	7	52,000	32,100		2	Automated
Central								
Buduatta	20,900	5,400	10	54,000	34,000		10	EnviroDome
Tormefa	21,200	6,000	8	48,000	26,800		15	Dinzengoff
Brong Ahafo								
Odumase-Adoe	21,200	4,500	12	45,000	24,800		30	Dinzengoff
Techiman	22,700	6,000					1	Malaysia
Eastern								
FOHCREC, Okumaning	18,900	7,500	6	45,000	23,100		8	EnviroDome
Aburi	20,400	7,500	10	75,000	54,600		6	Malaysia
Volta								
Vume	18,500	6,000	6	36,000	18,500		5	Dinzengoff
Northern								
Kubenya Dungu	18,600	5,400	5	27,000	8,400		1	Dinzengoff

Source: Survey results

Table 5: Number of greenhouses per location

NO. OF GREENHOUSES PER LOCATION	FREQUENCY	PERCENTAGE
1	2	18.2
2	2	18.2
5	1	9.1
6	1	9.1
10	1	9.1
14	1	9.1
15	1	9.1
25	1	9.1
30	1	9.1
1	1	9.1
TOTAL	**12**	**100.0**

Source: Survey results

4.3 Factors influencing vegetables production in Ghana

The study was also conducted to determine factors affecting greenhouse agricultural technology in Ghana and to make possible recommendation in improving the system, either on intensity of climate management and characteristic of farmer's affiliation who have adapted the technology. While greenhouse vegetable has increased in Ghana since its introduction in 1996, it is also known that farmers have been facing difficulties in attaining high yield, and that they also encounter challenges in pests and diseases management. Already, a significant number of greenhouses have been abandoned as a result of temperature challenges and inability to create market linkages for their produce. It is always necessary that, before a greenhouse producer decides to enter into production, undertaking a simple market survey to ensure the types of crops in need by customers is an important factor to consider. Another reason is the lack of quality inputs, adequate crop management including cropping schedules that will always meet market demand and unavailable good sources of water all lead to low yields in the greenhouse production in Ghana.

4.4 Types of greenhouses in Ghana and their suitability

There were three different types of greenhouses observed during the survey. The EnviroDome, Diezengoff Farmer's Kit (previously known as Amiran Farmer's Kit) and the Malaysian greenhouse. Based on the survey, the EnviroDome type of greenhouse had the highest yield as compared to the others (Table 4). This can be attributed to the fact that, the EnviroDome ventilation system is adapted to the conditions in the tropics and also the fact that training is given to those who use the EnviroDome system. They also have experiences in growing in the system over the year. EnviroDome greenhouse specifications are unique and well managed. Vegetables grown are of better quality, have premium prices, meet market timing, and regular selling to the markets among other advantages

4.5 Year of greenhouse establishment

From the finding of the study, it emerges that, between 2011 and 2016 the establishment of greenhouses was on an increase year after year at a percentage rate of (25.0%) (Table6). It is also seen that between 2017 and 2018 a significant number of greenhouses were abandoned, at the rate of 8.3%. This is attributed to the management strategies employed to maintain a standard greenhouse. Furthermore, the inability to control the average of temperature of the greenhouses is another factor of failure. Another explanation is, inability to create linkages between producers and buyers which leads to no break-even point, could also be a serious reason why greenhouses were been abandoned thus decreasing the number of greenhouses in the country. The average greenhouse size was ranged from 525m^2 to 135m^2 or highest and low respectively. The average size calculated were the standardized per meter squared to enable the comparison among 12 greenhouse sizes.

Table 6: Size and year of greenhouse establishment

YEAR ESTABLISHED	**FREQUENCY**	**PERCENTAGE**
2011	1	8.3
2012	1	8.3
2013	1	8.3
2014	2	16.7
2015	2	16.7
2016	3	25.0
2017	1	8.3
2018	1	8.3
TOTAL	**12**	**100.0**
SIZE OF GREENHOUSES	**FREQUENCY**	**PERCENTAGE**
135m^2	2	18.2
150m^2	1	9.1
200m^2	1	9.1
210m^2	1	9.1
220m^2	1	9.1
242m^2	1	9.1
320m^2	1	9.1

460m^2	1	9.1
525m^2	1	9.1
600m^2	1	9.1
Total	**11**	**100.0**
Undetermined size	1	
Total	**12**	**100.0**

Source: Survey results

On the question of the types of storage facilities and postharvest losses experienced in the greenhouse system production, the study revealed that 33% of the respondents' interviewed indicated that they did not have the facility because of arrangements made with off-takers of the produce. This reduced the postharvest losses they would have experienced to some extent. Another reason mentioned was they did not have enough capital to invest in advanced facility that will provide long period of storage for the produce. 33% of the respondents have cold room facility where they store the vegetables after harvesting before marketing the produce. This kept the produce fresh. Another set of 33% said they kept their harvested produce under normal room temperature before selling it to the buyers. They also indicated that lack of capital was the reason why they did not have a cold room for storage.

On post-harvest losses experienced using the greenhouse system, 25% of the respondents said they did not experience any loss while 58.3% experienced between 1-5% of loss, the remaining 16.7% have a post-harvest loss between 6-10% due to blossom end-rot and the harsh handling of the fruits during harvesting.

On the question of the cost of the greenhouse system purchased, 24.9% did not disclose the purchase price. They considered it a private matter and classified information. A total of 66.4% of the owners questioned who bought the greenhouse system revealed various purchase prices ranging from $ 15,000 to $ 24,000. 8.3% was a donation received from India.

Table7: Respondents feedback on storage facilities, postharvest losses and price of greenhouse

Type of storage facility	**FRENQUENCY**	**PERCENTAGE**
No facility	4	33.3
Cold room	4	33.3
Normal room temp.	4	33.3
Total	**12**	**100.0**
Postharvest losses experienced		
No losses	3	25.0
1-5%	7	58.3
6-10%	2	16.7
Total	**12**	**100.0**
PRICE OF GREENHOUSE (USD)		
Not Known	3	24.9
15,000	1	8.3
16,000	1	8.3
22,000	1	8.3
24,000	1	8.3
25,000	1	8.3
6,000	2	16.6
8,800	1	8.3
INDIAN DONATION	1	8.3
Total	**12**	**100.0**

Source: Survey results

4.6 Field Photos during Survey

4.6.1 FOHCREC- KADE


Plate 2: Tomato plants at their flowering stage **Plate 3: Nursery**


Plate 4: Loop Drip Irrigation system **Plate 5: Single Dome**

Plate 6: Dam (source of water) **Plate 7: Cooling pad**

Plate 8: Control panel **Plate 9: Sprinkler system**

Plate 10: Exhaust Fan

Plate 11: Tomato fruit

4.6.2 BREKUSO- EASTERN REGION

Plate 12: Greenhouse structure **Plate 13: Tomato plants**

Plate 14: Green pepper plants **Plate 15: Tomato fruit**

4.6.3 TORMEFA-KASOA

Plate 16: Single Dome **Plate 17: Nursery**

Plate 18: Inside the structure **Pl 19: Seedlings 4.6.4 GOMOA BUDUATTA**

Plate 20: Double Dome **Plate 21: Preparation of nursery site**

Plate 22: Seedling ready for transplant **Plate 23: Plant at flowering stage**

4.6.5 CSIR – KWADASO-KUMASI

Plate 24: Electric control panel **Plate 25: Single Dome**

Plate26: Borehole **Plate 27: Water pipe**

Plate 28: Pumping pipe **Plate 29: Tomato plant**

Plate 30: Cups for experiment **Plate 31: Respondents and researcher**

Plate 32: Tank **Plate 33: Sprinkler system and plant**

Plate 34: Loop Drip Irrigation system **Plate 35: Plant at flowering**

4.6.6 MOFA (WAAP) - Kubenya Dungu- Tamale

Plate36: Single Dome **Plate 37: Water tank**

Plate 38: Respondent and researcher

4.6.7 TECHIMAN

Plate 39: Harveted site **Plate 40: Harvested site**

Plate 41: Harvested site **Plate 42: Single Dome**

4.6.8 ASHAIMAN

Plate 43: Single Dome **Plate 44: Plum tomato**

Plate 45: Beefsteak tomato variety

4.6.9 DAWHENYA

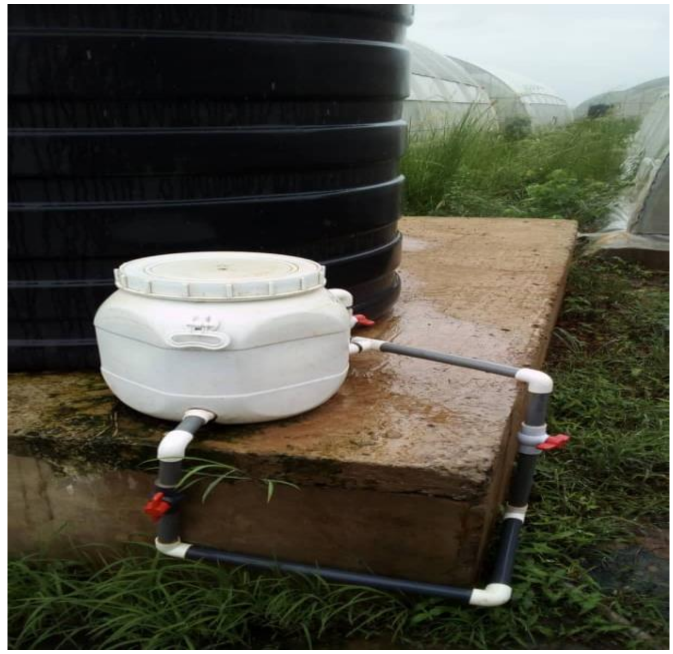


Plate 46: Single Domes **Plate 47: Tank**

Plate 48: Cherry tomatoes **Plate 49: Anna F1 tomato fruit**

4.7.0 VUME

Plate 50: Single dome **Plate 51: Tomato plant**

Plate 52:Tomato at fruiting stage **Plate 53: Dam (source of water)**

4.7.1 AKOMADAN

Plate 54: Respondents and researcher

Plate 55: Seed tray

Plate 56: Harvested cherry tomato site

4.7.2 ODUMASE-ADOEO



Plate 57: Tomato ready for harvesting **Plate 58: Tomato plant**

Plate 59: Abandoned Greenhouses in the Northern Region

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

During this survey, there were three types of greenhouses identified which are EnviroDome ventilation system, Dizengoff and the Malaysia greenhouses. It was observed at 11 out of the 12 locations visited, that the greenhouses did not meet the full complement of the required equipment needed for optimum production. This might be seen to translate in lower yields thus, resulting in low productivity and income. However, the greenhouses at the CSIR-Kwadaso, Kumasi that had almost all of the equipment required in a greenhouse for production leading to higher productivity and yields.

Another observation was research is that operating an EnviroDome ventilation greenhouse system for vegetable production is profitable than the Dizengoff and the Malaysia types. This is because the EnviroDome greenhouse system is more able to offer the needed micro-climate because of the special in-built features, for example the special ventilators (chimneys) and shade net which is very conducive to plant growth.

One other important factor which will affect the high productivity and yields in greenhouse production is Cocopeat, the major substrate used in the greenhouses production were very expensive. Farmers also lack technical know-how to appropriately operate the greenhouse which may lead to abandoning the use of greenhouses and may possibly reduce the number.

5.2 Recommendations

Government should promote and support the development of commercial greenhouse vegetable sector in Ghana to have all the acceptable requirements present.

Ministry of Food and Agriculture should partner with GhanaVeg to support the climatic data management in the greenhouses by producing a well-trained management staff who will consequently train farmers.

Utilizing an effective and affordable growing medium must be made a priority in greenhouse technology.

Improve integrated pest management systems for greenhouse farming.

A country-wide seed supply-chain that would support the availability of high quality planting materials must be set-up.

Biological control agents must be identified to manage diseases and pests that would attack the greenhouse structure.

REFERENCES:

Agyeman-Duah, I. (2008). An Economic History of Ghana: reflections on a half century of progress. *Boulder, CO: Lynne Rienner*.

Ana, M. (2017).Why do you need greenhouse thermometer and hydrometer? Agrihome expression. Greenhouse vegetable farming: *Ideal for vegetable production in Ghana*. https://agrihomegh.com/greenhouse-vegetable-farming/ (Retrieved on May 2, 2018).

Baudoin, W., Nono-Womdim, R., Lutaladio, N., Hodder, A., Castilla, N., Leonardi, C., ... & Duffy, R. (2013). Good agricultural practices for greenhouse vegetable crops: Principles for mediterranean climate areas. *FAO plant production and protection paper (FAO)*.

Bowery Farming. (2017). A brief history of modern farming. https://news.boweryfarming.com/https-medium-com-boweryfarming-a-brief-history-bda861d333d3 (Retrieved on April 27, 2018).

Başak, H., & Doğus, M. (2016). Vegetable Production Potential of Turkey. *Journal of Experimental Agriculture International*, 1-18.

Bruno, G. (2012). A short history of the Greenhouse. https://davesgarden.com/guides/articles/view/3607 (Retrieved on May 7, 2018).

Bascombe, K. (2013). New technology for detecting pests and diseases. https://blog.plantwise.org/2013/03/21/new-technology-for-detecting-pests-and-diseases/ (Retrieved on May 22, 2018).

Curry, C. J., Lopex, R. G., Krug, B. A., Owen, G. & Brain, E. (2018). How to measure greenhouse light with quantum meters. https://www.greenhousegrower.com/technology/how-to-measure-greenhouse-light-with-quantum-meters/ (Retrieved on May 30, 2018).

Dickerson, G. W. (1996). Greenhouse Vegetable Production. New Mexico State University and U.S. Department of Agriculture cooperating. https://aces.nmsu.edu/pubs/_circulars/CR556.pdf (Retrieved on April 30, 2018).

Elings, A. (2011). A Greenhouse Crop Production System for Tropical Lowland Conditions. Thesis submitted to the department of Crop Physiologist and Modeller Wageningen UR Greenhouse Horticulture, Wageningen University and Research Center. (Retrieved on April 3, 2018).

Elings, A., Saavedra, Y., & Nkansah, G. O. (2015). *Strategies to support the greenhouse horticulture sector in Ghana* (No. 1353). Wageningen UR. Engindeniz, S., & Tuzel, Y. (2006). Economic analysis of organic greenhouse lettuce production in Turkey. *Scientia Agricola*, *63*(3), 285-290. *doi: http://dx.doi.org/10.1590/S0103-90162006000300012*

Ghana Statistical Service, (2018). Statistics for development and progress. (Retrieved May 19, 2018).

Ghani, S., Bakochristou, F., ElBialy, E. M. A. A., Gamaledin, S. M. A., Rashwan, M. M., Ayman, M. A., & Salman, M. I. (2018). Design challenges of agriculture greenhouses in hot and arid environment–A review. *Engineering in Agriculture, Environment and Food*.

Gruda, N. &Popsimonova, G. (2018)**.** Current situation and future trends of protected cultivation in southeast Europe. https://www.researchgate.net/publication/317043027_Current_situation_and_future_trends_of_protected_cultivation_in_South_East_Europe (Retrieved on May 3, 2018).

Guodaar, L. (2015). *Effects of climate variability on tomato crop production in the Offinso North District of Ashanti region* (Doctoral dissertation).

Hamilton, C., & Quiggin, J. (1997). Economic Analysis of greenhouse policy. *A layperson's guide to the perils of economic modelling. The Australia Institute Discussion Paper*, *15*.

Hickman, G. W. (2010). Tropical Greenhouses: Design, construction and supply list. Cuesta Roble Consulting, University of California, USA. (www.cuestaroble.com). (Retrieved on May 19, 2018).
Huete, J.S.L. (2018). Different covering materials for greenhouse. (www.jhuete.com). (Retrieved on May 28, 2018).

Hickman, G. W. (2018). International Greenhouse Vegetable Production-Statistics.https://www.researchgate.net/publication/323072341_Economic_Analysis_of_Protected_Cultivation_Comparison_of_Vegetable_vs_Fruit (Retrieved on May 10, 2018).

Ingram, K.L. (2014). Traditional income statement or absorption costing income statement.https://accountinginfocus.com/managerial-accounting-2/costing-methods/the-traditional-absorption-costing-income-statement/ (Retrieved on April 10, 2018).

Kittas, C., Katsoulas, N., Bartzanas, T., & Bakker, J. C. (2013). Greenhouse climate control and energy use. In *Good Agricultural Practices for greenhouse vegetable crops: Principles for Mediterranean climate areas* (No. 217, pp. 63-95). ISHS/FAO/NCARE.

Kropff, M.J. (2011). A Greenhouse crop production system for tropical lowland. Thesis submitted to wageningen University. http://edepot.wur.nl/176828 (Retrieved on April 3, 2018).

Kittas, C., Katsoulas, N. &Bartzanas, T. (2017). Structure: design, technology and climate control.

Kacira, M., Sase, S., Kacira, O., OKUSHIMA, L., ISHII, M., Kowata, H., & Moriyama, H. (2004). Status of greenhouse production in Turkey: Focusing on vegetable and floriculture production. *Journal of Agricultural Meteorology*, *60*(2), 115-122.

Kumar, U., & Hosamani, V. (2009). Economic Consequence of pesticide use in paddy Koppah District, Karnataka.

Larochelle, C., Alwang, J., Travis, E., Barrera, V. H., & Dominguez Andrade, J. M. (2019). Did you really get the message? Using text reminders to stimulate adoption of agricultural technologies. *The Journal of Development Studies*, *55*(4), 548-564.

Maboko, M. M., Du Plooy, C. P., & Bertling, I. (2011). Comparative performance of tomato cultivars cultivated in two hydroponic production systems. *South African Journal of Plant and Soil*, *28*(2), 97-102.

Magsumbol, J. A. V., Cagatan, G. K. B., Lim, L. G., & Dadios, E. P. (2017, December). Development of a cooling system for tomato using fuzzy logic approach. In *2017IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM)* (pp. 1-4). IEEE.

Mindel, D., Gaveh, E., Lumor, M. & Nkansah, G. O. (2014). Feasibility report on Greenhouse vegetable production. (Unpublished report)

Mwangi, W. J. (2012). Comparative analysis of Greenhouse versus open-field small scale tomato production in nakuru-north district, Kenya. http://41.89.96.232:8080/xmlui/handle/123456789/1113 (Retrieved on April 3, 2018).

NSW Department of primary industries, (2018). Protected cropping and the NSW planning & approvals process. https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/825970/protected-cropping-and-the-nsw-planning-and-approvals-process.pdf (Retrieved on April 3, 2018).

Nkansah, G. O. (2016-2017). Unpublished report.

Sabir, N., & Singh, B. (2013). Protected cultivation of vegetables in global arena: A review. *Indian Journal of Agricultural Sciences*, *83*(2), 123-135.

Shipp, L., Johansen, N., Vänninen, I., & Jacobson, R. (2009, June). Greenhouse climate: an important consideration when developing pest management programs for greenhouse crops. In *International Symposium on High Technology for Greenhouse Systems: GreenSys2009 893* (pp. 133-143).

Singh, M. C., Singh, J. P., Pandey, S. K., Mahay, D., & Srivastava, V. (2017). Factors Affecting the Performance of Greenhouse Cucumber Cultivation: A Review. *Int. J. Curr. Microbiol. App. Sci*, *6*(10), 2304-2323.

Sringarm, K., Max, J. F. J., Saehang, S. Spree, W. &Kumpiro, S. Müller, M. (2013). Protected Cultivation of Tomato to Enhance Plant Productivity and Reduce Pesticide Use.

http://www.tropentag.de/2013/abstracts/links/Spreer_39Mx6BLn.pdf (Retrieved on April 5, 2018).

Smith,T., Cox, D., Clifton, N., Lopes, P., Bartok, J. M. &Laslola, T. (2010). Greenhouse Industry best management practices. https://ag.umass.edu/greenhouse-floriculture/greenhouse-best-management-practices-bmp-manual (Retrieved on April 5, 2018).

Vali, M. K.K. S., Priyankai, S. K., Deepthi, V. V. H. C., Lakshmi, H. M. & Tejeswari, Y. (2017). Automatic Farm Monitoring and Controlling System by using GSM Technology. http://internationaljournalssrg.org/IJECE/2017/Special-Issues/ICEEMST/IJECE-ICEEMST-P119.pdf (Retrieved on April 5, 2018).

World development report. (2008). Agriculture for Development. https://www.brettonwoodsproject.org/2007/01/art-548775/ (Retrieved on April 5, 2018).

Wachira, J. M., Mshenga, P. M., & Saidi, M. (2014). Comparison of the profitability of small-scale greenhouse and open-field tomato production systems in Nakuru-North District, Kenya. *Asian Journal of Agricultural Sciences*, *6*(2), 54-61.

Yilmaz, I., Sayin, C., & Ozkan, B. (2005). Turkish greenhouse industry: past, present, and future. *New Zealand Journal of Crop and Horticultural Science*, *33*(3), 233-240.

APPENDICES:

Appendix 1

Interview Schedule:

University of Ghana

Current status of greenhouse production survey 2018

Introduction

I am carrying out a research survey in 7 regions of Ghana and would like to conduct interviews with owners and managers operating the greenhouses in Ghana. The survey's objective is carrying out on the type of greenhouse adapted, equipment and climate management and economic analysis on vegetables greenhouse producers in the production systems at the various visiting sites in terms of: the quality of greenhouse, factors affecting the greenhouse and their profitability. Respondents are randomly selected to participate VOLUNTARILY and their participation in this survey is highly appreciated. Opinions gathered in the survey will be completely CONFIDENTIAL and will be analyzed solely for academic purposes. The research findings will benefit the greenhouse producers, the government and other greenhouse vegetables stakeholders, so as to improve the production of quality greenhouse in Ghana and even as well as the researcher's country.

GENERAL INFORMATION

Date: __________________

Time of interview: ______________________________________

Enumerator's Name: ______________________________________

Respondent's Name_______________________________________

Region ____

Type of greenhouse

1. Envirodome (...) 2. Dizengoff type (...) Malaysia (…)

SECTION A: GENERAL INFORMATION

A1. Which year did you start greenhouse production? _______

A2. How many greenhouses do you have? ---------------------

A3. What is the size of your greenhouse structure? ---------------

A4. What is the total cost of one greenhouse structure GHC (……) $ (…..)

A5. How do you rate the performance of your greenhouse production 1? Very good profit (...) 2. Satisfactory profit (...) 3. Little profit (...) 4. No profit (...) 5. Loss (...) 6. Don't know (...)

A6. Have you established any input procurement linkages 1? Yes (…) 2. No (…)

A7. What is your source of water 1? Borehole (…) 2. Dam (…) 3. Other (specify) (…)

A8. If "Yes" Specify--

A9. Is it a reliable buying link 1? Yes (…) 2. No (…)

A10. If “Yes” how does this positively impart your production -----------------------------------?

SECTION B: PRODUCTION SYSTEM

B1. Have you had any training in greenhouse vegetables production? 1. Yes (…) 2. No (…)

B2. If “Yes” What type of training---

B3. Where did you acquire your training? 1. Ghana (…) 2. Foreign land (…)

B4. Did the training content met your expectation as relates to the greenhouse production?

1. Yes(…) 2. No (…)

What did you pay for the training? 1. Scholarship (…) 2. Amount paid (….)

B5. Are you a member of any farming organizations? 1. Yes (…) 2. No (…)

B6. If “yes” specify--

B7. Does the organization offer any training? ---------------------------------------

B8. If “yes” specific--

B9. Is the training beneficial to your work in the greenhouse? 1. Yes (…) 2. No (…)

B10. Are you collaboration with any institution? 1. Yes (…) 2. No (…)

B11. If “yes” specify 1. University (…) 2. Research center (…)

B12. What is the nature of your collaboration? 1. Support (…) 2 Training (…) 3. Research (…)

B13. What good agricultural/agronomic practices do you use? ----------------------------------

B14. What type of storage facility do you have? 1. Refrigerator (…) 2. Cold room (…) 3. Normal room (…) 4. No storage facility (…)

B15. What is the estimated % postharvest losses for your produce? 1. 1-5 (…) 2. 6-10 (…) 3. No losses (…)

B16. What harvesting methods do you use? 1. Hand harvest (…) 2. Harvesting tools (…)

B17. If your answer is "#2" Specify--

B18. Do you take farm record on your farm? 1.Yes (…) 2. No (…)

B19. If "yes" what type of record do you keep? 1. Farm diary (…) 2. Sales record (…)

3. Production (…)

SECTION C: MARKET AND PRODUCTION RECORDS

C1. What type of crops do you grow? 1. Vegetables (…) 2. Fruits (…) 3. Ornamentals (…)

C2. How many crops are you currently producing? 1. One (…) 2. Two (..) 3. Three (…) 4. (…) 5. Five (…)

C3. Please mention the names of the crops---

C4. How many growing circles do you do in a year 1? One (…) 2. Two (…) 3. Three (…)

C5. What unit do you use to measure your produce 1? Kg (…) 2. Bags (…) 3. Crate

C6. How many Kg/Bag/Crate do you accumulate at the end of every growing circles...?

C7. Do you do any off-take arrangement for your produce? 1. Yes (…) 2. No (…)

C8. If “yes” What are the positives associated with the arrangement…………………………..

SECTION D: INPUT ACCESSIBILITY

D1. How easily accessible are your inputs for the greenhouse production?

NO.	VARIABLE TYPE	EASILY ACCESSIBLE	NOT EASILY ACCESSBILE	NOT ACCESSIBLE	SOURCE
1	Seed				
2	Substrate				
3	Agro-chemicals				
4	Electricity				
5	Water				
6	Fuel				
7	Labour				
8	Trellising rope				

D2. Quantity and type of input supply

NO.	VARIABLE TYPE	TYPE	QUANTITY/ NUMBER USED	SOURCE OF INPUTS
1	Seed			
2	Substrate			
3	Agro-chemicals			
4	Electricity			
5	Water			
6	Fuel			
7	Labour			
8	Trellising			
9	Investment			
10	Type of Greenhouse			

SECTION E: COST INFORMATION FOR VEGETABLE PRODUCTION

NO.	TYPE OF VEGETABLES	UNITE OF MEASURE OF PRODUCE COST	PRICE PER SPECIFIED UNIT (GHC)	COST PER GROWING CIRCLE	TOTAL COST PER YEAR
1	Tomato				
2	Cucumber				
3	Hot pepper				
4	Lettuce				

SECTION F: MANAGEMENT OF CLIMATIC DATA

NO.	EQUIPMENT	AVALIABLE	NOT AVALIABLE	COST	SOURCE
1	Date Logger				
2	Light meter				
3	Thermohygrometer				
4	Electrical connectivity				
5	Fertigation Tank				
6	Loop Drip System				
7	Soda Radiation				
8	Weighing Scale				

E1. Do you have any expertise use for repair/maintenance of these equipment?

1. Hire (…) 2. Self-expertise (…)

E2. Are they efficiently and continuously being used? 1. Yes (…) 2. No (…)

E3. Are they serving their purposes or producing results? 1. Yes (…) 2. No (…)

Appendix 2

Thermophygrometer **pH meter**

Electrical Connectivity

Data Logger


Pro
106
LUX
26.0
SMART
SENSOR
HOLD
MIN
MAX
LUX
FC
LIGHT
°C/°F
Digital Lux Meter
AS813
Digital Lux Meter
AS813

Light meter