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A SYSTEMS THINKING APPROACH TO ADDRESS THE COMPLEXITY OF

AGRIBUSINESS FOR SUSTAINABLE DEVELOPMENT IN AFRICA:

A CASE STUDY IN GHANA

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degree of Doctor of Philosophy

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Dedicated to Mr Albert Kojo Banson, Sandra Banson and the late Cecilia Tornyedzi

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List of Abbreviations

AAGDS	Accelerated Agricultural Growth and Development Strategy
AGRA	Alliance for a Green Revolution in Africa
BBN	Bayesian belief network
CAADP	Comprehensive African Agricultural Development Plan
CBBR	Cat Ba Biosphere Reserve
CLD	causal loop diagrams
CPT	Conditional Probability Table
CSA	Community Supported Agriculture
ECOWAP	Economic Community of West African States Agricultural Policy
ELLab	Evolutionary Learning Laboratory
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FASDEP	Food and Agriculture Sector Development Policy
GDP	Gross Domestic Product
IFAD	International Fund for Agricultural Development
MESTI	Ministry of Environment, Science, Technology and Innovation
MOFA	Ministry of Food and Agriculture
NEPAD	New Partnership for Africa's Development
NGO	non-government organisations
NTFP	non-timber forest products
PSIA	poverty and social impact analysis
R&D	research and development
SCP	structure, conduct and performance
RQs	research questions
US	United States

Abstract

African countries have comparative advantages in the production and export of primary commodities; however, they face many sustainability challenges in the agricultural sector. Since the democratisation of many African countries—notably Ghana—a number of interventions, costing billions of dollars, have been implemented to overcome the challenges facing the agricultural industry, but with little success. The agricultural industry is characterised by complex challenges such as famine, food insecurity, poor soil and quality standards, political instability, inappropriate agricultural practices, and the depletion of natural resources. These challenges have worsened the plight of African farmers. The increasingly complex nature of the agricultural industry in Africa has led to an urgent need for the use of a systemic rather than traditional approach to solve agricultural problems.

Capacity building using a systems thinking approach and the concept of an Evolutionary Learning Laboratory during a series of stakeholder workshops in Ghana, has had a remarkable effect on the ability of the agricultural industry to evolve, improve and increase its efficacy. Causal Loop and Bayesian Belief Network (BBN) modelling were used to develop systems models to determine the components and interactions between the policy and the social, environmental and economic dimensions of the industry. Insights were made into potential system behaviours and leverage points for the systemic interventions required for sustainable agricultural development.

The results reveal that the behaviour over time of agricultural productivity is declining, although new agricultural lands are being exploited, leading to environmental degradation. System archetypes as diagnostic tools have contributed to understanding the cause of a fix 'now', which gives rise to a much bigger problem to fix 'later'. The results illustrate how the structure, conduct and performance elements of the agricultural industry interact together to influence the survival and growth of the sector. The study identifies that stakeholders adopt several strategies to survive and compete, leading to overexploitation of the ecosystem.

Results from the BBN models indicate that the implementation of systemically determined interventions, policies and strategies could result in the chance of raising 'agricultural productivity' as high as 92.2% from 57.5%, and it might be plausible to reduce poverty levels from 44.9% to 10.0%. This would also lead to a significant increase in farmers' yields and profits. These BBNs are used for scenario testing to determine the potential outcomes of different systemic interventions by observing what happens to the system as a whole when a particular intervention/strategy or combination of interventions/strategies is implemented—that is, before any time or money is invested in implementation.

This approach provides clarity on dealing with complex sustainability challenges and should gradually replace the reductionist approach (e.g., short-term quick fixes and treating the symptoms) in dealing with challenges and developing policies. The systems models will help governments to anticipate the long-term consequences of their decisions and actions, as well as help to avoid significant unintended consequences of policies and strategies such as 'silo mentality' and 'organisational myopia'.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without prior approval of the University of Adelaide and, where applicable, any partner institution responsible for the joint award of this degree. I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the *Copyright Act 1968*. The author acknowledges that copyright of published works contained within this thesis resides with the copyright holder(s) of those works. I also give permission for the digital version of my thesis to be made available on the web via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

I hereby certify that this thesis is submitted in the form of a series of published papers of which I am the main author. I have included as part of the thesis a written statement from each co-author, and endorsed by the Faculty Assistant Dean (Research Training), attesting to my contribution towards the multi-authored publications.

Signed: Date:9th September 2016

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List of Publications by the Candidate

Published/under review Journal Papers (these papers form the main body of the PhD Thesis)

1. **Banson, KE,** Nguyen, NC, Bosch, OJH & Nguyen, TV 2015, 'A systems thinking approach to address the complexity of agribusiness for sustainable development in Africa: a case study in Ghana', *Systems Research and Behavioral Science*, vol. 32, no. 6, pp. 672–688. doi:10.1002/sres.2270.

2. **Banson, KE,** Nguyen, NC & Bosch, OJH 2016, 'A systems thinking approach to the structure, conduct and performance of the agricultural sector in Africa: a case study—Ghana', *Systems Research and Behavioral Science*, (under review: 1st round of comments from peer reviewers received; revised manuscript has been submitted)

3. **Banson, KE,** Nguyen, NC & Bosch, OJH 2016, 'Using system archetypes to identify drivers and barriers for sustainable agriculture in Africa: a case study in Ghana', *Systems Research and Behavioral Science*, vol. 33, no. 1, pp. 79–99. doi:10.1002/sres.2300.

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Peer-Reviewed Conference Publications

1. **Banson, KE,** Nguyen, NC & Bosch, OJH 2015, '"The greater push" for growth and sustainability in Africa: evidence from Ghana', proceedings of the 59th Annual Meeting of the International Society for Systems Sciences, 2–7 August, Berlin, Germany.

2. **Banson, KE,** Nguyen, NC & Bosch, OJH 2015, 'Systemic structure, conduct and performance of the agricultural industry in Africa: evidence from Ghana', proceedings of the 59th Annual Meeting of the International Society for Systems Sciences, 2–7 August, Berlin, Germany,
http://journals.isss.org/index.php/proceedings59th/article/viewFile/2480/859.

3. **Banson, KE,** Nguyen, NC & Bosch, OJH 2014, 'Systemic intervention to tackle the constraints and challenges facing stakeholders and the performance of the agricultural sector in Ghana', paper presented at the 9th Annual System of Systems Engineering Conference, 9–13 June, Adelaide, SA.

4. **Banson, KE,** Nguyen, NC, Bosch, OJH & Nguyen, TV 2013, 'A systems thinking approach to address the complexity of agribusiness for sustainable development in Africa', proceedings of the 57th Annual Meeting of the International Society for Systems Sciences, HaiPhong, Vietnam,
   http://journals.isss.org/index.php/proceedings57th/article/view/2119.

5. **Bosch, OJH,** Nguyen, NC, Ha, TM & Banson, KE 2015, 'Using a systemic approach to improve the quality of life for women in small-scale agriculture: empirical evidence from Southeast Asia and Sub-Saharan Africa', proceedings of the Business Systems Laboratory 3rd International Symposium 'Advances in Business Management. Towards Systemic Approach'. January 21-23, 2015, Perugia

List of Additional Publications

1. **Banson, KE,** Bosch, OJH & Nguyen, NC 2015, 'A systemic intervention to access resource impact on the quality of life among women farmers in developing countries: evidence from Ghana', *Academia Journal of Agricultural Research*, vol. 3, no. 2, pp. 15–22. doi:10.15413/ajar.2015.0108.

2. Nguyen, NC, Bosch, OJH, Ong, FY, Seah, JS, Succu, A, Nguyen, TV & **Banson, KE** 2015, 'A systemic approach to understand smartphone usage in Singapore', *Systems Research and Behavioral Science*, vol. 33, no. 3, pp. 360–380. doi:10.1002/sres.2348.

3. Nguyen, NC, Bosch, OJ, **Banson, KE,** Ting, OLJ, Xuan, JG, Hui, MS & Lim, Z 2015, 'A systems thinking approach to address the complex issue of plastic surgery in South Korea', *International Journal of Markets and Business Systems*, vol. 1, no. 2, pp. 108–135.

4. Nguyen, NC, **Banson, KE,** Bosch, OJ, Nguyen, T, Tan, L, Goh, G, Lim, O & Jupary, Z 2016, 'The economic importance of social graciousness index: a systemic approach to Singapore case', *International Journal of Markets and Business Systems* (In press).

Chapter 1: Introduction

1.1 Importance of Agriculture in Africa

Africa is populated with more than 900 million people, 70% of whom are engaged in agriculture for full-time employment (Bationo & Waswa 2011; Mahajan 2009; Ojukwu et al. 2010). Agriculture accounts for 33% of the national income and 40% of total export earnings (Bationo & Waswa 2011). Further, people in rural areas depend on agriculture for part of their household income, and it is the main generator of savings and tax revenues. Agriculture is the backbone of most African economies. In addition to being an important source of household income, it constitutes the core of raw materials for the manufacturing sector; for example, fibrous materials, animal products, natural rubber and vegetable oils are used in the manufacture of non-food items. In most African rural communities, agriculture supports 70%–80% of the total population, including 70% of the continent's extremely poor and undernourished. Agricultural production and trade are central to the functioning of domestic markets, the fight against poverty, the provision of employment and the quest for greater national food security (Losch 2004), and they also provide other agriculture-related jobs (Gibbon & Olukoshi 1996). Services connected to the promotion of agricultural production and productivity also occupy a significant position in most African economies (Bationo & Waswa 2011). In summary, agriculture continues to provide one of the strongest bases for promoting overall economic development in Africa, including opportunities for the growth and expansion of the industrial sector.

Despite the importance of agriculture in the African economy, it is characterised by low productivity, limited access to technology, low human capacity to adopt new skills, poor-quality products, poor and un-remunerative external markets, poor service quality, and high production and transaction costs (Eifert, Gelb & Ramachandran 2008; Kydd et al. 2004; Wiebe et al. 2003). It is also constrained by high levels of competition and regulation, and by a lack of appropriate technology (Bationo & Waswa 2011; Nutsukpo et al. 2012; Ortmann 2000, 2005). Over the past 20 years, there has been an average increase in agricultural production of 3.2% due to an increase in land under cultivation rather than an increase in productivity. For example, a 229% increase in cultivated farmland accounted for only a 70% increase in regional production (Oxford Business Group 2010). The average agriculture growth rate in real terms has been stagnant at about 1.7% to 1.9% since 1965 (Cleaver 1993). According to Cleaver (1993), the agriculture growth rate is far lower than the population growth rate, which has increased from 2.7% per annum between 1965 and 1980 to 3.1% per annum since the 1980s. These and other significant factors have exposed 200 million people in Africa to the vulnerability of food insecurity (Ojukwu et al. 2010). This is further

demonstrated by food imports and aid, which have increased by 4% and 7% per annum respectively since 1974 (Cleaver 1993) and have placed more pressure on economic growth, which has been steady at 3% for the past 20 years (Ojukwu et al. 2010). Currently, it is estimated that Africa will be able to feed less than half of its population from domestic agricultural production by 2018 (Ojukwu et al. 2010). Over the past two decades, agricultural GDP per farmer has risen by less than 1% in Africa relative to 2% and 3% per annum in Asia and Latin America respectively (Nutsukpo et al. 2012; Ojukwu et al. 2010). According to Boko et al. (2007), there has been a 20% to 40% decline in rainfall in Africa over the past 50 years, which has led to serious consequences for the savanna or dry land areas. Per-hectare yields for most crops are among the lowest in the world, only increasing by an average of 42% between 1980 and 2005, and accounting for just 30% of the increase in agriculture and food production (Bationo & Waswa 2011).

An improvement in agricultural performance may increase rural incomes and purchasing power for a large number of Africans. According to the Economic Community of West African States Agricultural Policy (ECOWAP) (2008), farmers have been trained in agronomics and are working harder, and African governments have provided input subsidies and irrigation facilities, but productivity has not increased. Research on agronomic diversity has not been able to solve challenges and has been of little help until now, often favouring traditional or vertical approaches that take insufficient account of the global nature and complexity of production and agrarian systems.

The Singer–Prebisch thesis postulates that exports fetch less on international markets because agricultural products have a relatively low-income elasticity of demand and supply (Todaro & Smith 2009). This implies that the prices and revenues received will decline over time and contribute to export earnings instability in developing countries, while regional produce must compete with cheap imports generated by the subsidies given to producers in developed countries. The net result is that this agricultural model, which is largely dependent on natural resources and poorly paid labour, has become unviable. If it is to be sustainable in the long term, agriculture needs to be transformed so that it may provide a way out for the already worsened plight and competition endured by most African farmers, whose livelihoods depend upon it.

The agriculture industry is highly complex. To help address the above challenges, a new methodological approach is needed that moves away from a 'linear' way of solving problems towards a systemic perspective that focuses on the interconnectedness among the components of the entities. This avoids the danger of 'silo mentality' and 'organisational myopia'. This study seeks to use a systems thinking approach to holistically address sustainability

challenges. 'Systems thinking' is based on the belief that the component parts of a system of interest can be best understood in the context of the connectedness between the entities that comprise the system, rather than in isolation (Sherwood 2002). According to Sherwood (2002), systems thinking focuses on a cycle rather than linear cause and effect.

1.1.1 Study Area: Importance of Agriculture to Ghana's Economy

In 2007, Ghana discovered oil in addition to its relatively diverse and rich natural resource base, and it is currently producing approximately 85,000 barrels of oil per day (Global Edge 2013). Despite the oil and mineral wealth being exploited, agriculture remains a mainstay of the economy, accounting for 40% of GDP and about 70% of formal employment (Chisenga, Entsua-Mensah & Sam 2007; Khor & Hormeku 2006). The importance of agriculture is even greater than these figures suggest, as ecological and cultural boundaries also depend on agriculture, which is essential to sustainability. Other sectors of the economy are also linked to agriculture, including the processing, transport and trade of agricultural products and materials (Khor & Hormeku 2006). Thus, the agriculture sector (and especially the subsectors that produce food) is critical in the provision of incomes and livelihoods, and developments within this sector are important in terms of attaining the Millennium Development Goals of eliminating poverty (Pisupati & Warner 2003). In recent years, agricultural growth in Ghana has been positive overall, but much of this growth has resulted from area expansion rather than increased yields (International Food Policy Research Institute 2007). The agriculture sector, which has undergone significant economic, social and political changes since the beginning of the democratisation process in 1957, is increasingly facing challenges such as vulnerability to food insecurity. The combination of liberalisation and reforms of the 1970s, which resulted from the economic transformation, also exposed the agriculture sector to the adverse effects of globalisation, such as increased and unfair competition, which hinders the growth of infant industries (Chitiga, Kandiero & Ngwenya 2008; Khor & Hormeku 2006).

These effects, along with the marginalisation of farmers—especially smallholders—is further worsened by farmers' inability to handle the costs and administrative burdens of compliance with global standards. Large importers in Europe play a decisive role in structuring the production and marketing of primary products exported from Ghana. The requirements that importers specify for innovation—for instance, new product development, delivery, food safety and quality systems—determine what types of producers and exporters are able to compete in the export market and maintain access to the agribusiness chain (Humphrey 2005). These place smallholder producers in a marginalised position in the export sector.

1.1.1.1 Interventions to Uplift the Agricultural Sector in Ghana

There have been many attempts to uplift the agricultural industry in Africa and, for that matter, in Ghana. Foreign investors from land-scarce countries opportunistically seek to develop agribusiness projects in Ghana and other African countries. Concerns about Ghana's agricultural productivity growth have led the New Partnership for Africa's Development (NEPAD) to set up the Comprehensive African Agricultural Development Plan (CAADP) (Kolavalli et al. 2010). Under Kofi Annan's leadership, the Rockefeller and Gates Foundations have supported the new Alliance for a Green Revolution in Africa (AGRA) initiative (Bell, Milder & Shelman 2008). In 2007, the World Bank dedicated its annual world development report to agriculture (Bell, Milder & Shelman 2008). Agricultural development, including food self-sufficiency, is an important component of the Ghanaian Government's Vision 2020 (Kolavalli et al. 2010). To meet these objectives, the government adopted an 'Accelerated Agricultural Growth and Development Strategy in Support of Vision 2020' for 1997–2007 (Khor & Hormeku 2006). The aim is to achieve an annual real growth rate of 6% in the sector relative to the average annual growth rate of 4% recorded between 1995 and 1999, substantially based on exports of primary commodities. This growth is to be achieved by adopting open-market principles to encourage private sector investment, and through a greater devolution of responsibilities from the central government to district assemblies (Khor & Hormeku 2006).

Since 1960, there have been numerous and encouraging modernisation efforts to improve the agricultural sector in Ghana. Traditional and reductionist approaches through collaborations between research institutions, universities, end users and other development partners have attempted to address many of the constraints facing the agriculture industry. However, agricultural production and productivity continue to decline (Traoré 2009). According to Nguyen and Bosch (2012) and Bell and Morse (2005), these issues and challenges cannot be addressed and solved in isolation and along single dimensions, as in the past. They argue that the traditional and linear approach to sustainable development is one of the major impediments to sustainability. This explains the slow, negative or lack of progress in Africa and Ghana, as the industry's multidimensional, complex and dynamic makeup make it difficult to solve problems in isolation.

1.2 Justification for the Research

African governments and agriculture proponents currently have neither adequate information nor the necessary tools required to analyse the performance of policies affecting the food and agricultural sectors. They are under increasing pressure to make the right management decisions in the face of a continually changing political and socioeconomic landscape. The

local and global challenges currently facing the agricultural sector in Africa (including Ghana) are highly complex in nature. History suggests that these problems cannot be solved in isolation and with single-dimensional mindsets and tools. Agricultural sustainability may benefit from a systemic approach to interventions and capacity-building based on systems thinking and complexity management to address challenges holistically and deliver the desired sustainable outcomes. Nguyen and Bosch's (2012) ongoing Cat Ba Biosphere Reserve (CBBR) sustainability project in Vietnam demonstrates these approaches, and its lessons can be applied to the agricultural sector.

In this research, systems models are developed to provide an understanding of the dynamics, interconnectedness and relationships present within the agricultural industry. The research is conducted using a systems thinking approach and tools such as causal loop diagrams (CLDs) and Bayesian belief network (BBN) models to demonstrate its application in effectively addressing complex sustainability issues affecting the agriculture sector. This research seeks to address the agricultural system's complexity by gathering the 'mental models' of various stakeholders involved in the agricultural sector in Ghana. The results and approach will help decision makers and managers to anticipate the long-term consequences of their decisions and actions, as well as significant unintended consequences of policies and strategies, and avoid the danger of 'silo mentality' and 'organisational myopia'. The process aims to provide a common language for diverse stakeholders, such as farmers, policymakers, exporters and researchers, for deep dialogue and consensus building.

1.3 Research Questions

This thesis addresses the following research questions:

1. What are the pressing constraints and challenges to agricultural systems' management and enactment of agricultural policy?
2. What is the interaction of the structure, conduct and performance (SCP) of the agricultural sector in Ghana?
3. What are the opinions of stakeholders concerning how the agricultural system works, the barriers to success and the system drivers?
4. What are the possible new strategies or solutions that need to be designed to overcome these challenges or problems in the agricultural sector?
5. How can competitiveness be increased through the formulation of management policies that will help in the proper allocation of a country's scarce resources?

1.3.1 Aims and Objectives of the Study

In addressing the questions identified, this thesis aims to:

- provide an understanding of the dynamics, interconnectedness and relationships present within the agricultural industry
- identify leverage points and key research areas to help prioritise actions and understand the importance of addressing core issues rather than symptoms within the agricultural system to enact effective changes
- reveal the elegant simplicity underlying the complexity of management issues in agribusiness
- develop a systems model to capture key forces and dynamics affecting the agricultural industry in Ghana
- introduce and implement an integrated approach in youth agribusiness development with the participation of all stakeholders and link them to the value chain.

These research questions and their outcomes have been published in academic journals as papers one to five respectively (see Chapters 2 to 6). Paper 5 of this thesis have been awarded the Best PhD Award – "Anatol Rapoport Memorial Award" in 2015 by the International Society for the Systems Sciences (ISSS) during presentation of the paper at the ISSS Berlin conference 2015. The candidate has also been awarded two certificates from the Faculty of Professions, University of Adelaide as "the most contemporary and innovative presentation" and as "the most collegiate presenter" in 2014.

1.4 Theoretical Framework and Methods

The agriculture industry in Africa is complex. To unravel this complexity for adaptive sustainable management, stakeholders within the industry were involved in a series of workshops in the case study area, Ghana. Each stakeholder has a mental model of the agriculture system and its purpose depending on their individual understanding, experience, education and values. Thus, among stakeholders, there can be a multitude of views about the sustainability of agricultural systems and the factors that affect sustainability. For this reason, stakeholders in the agricultural industry (farmers, extension agents, research scientists, policymakers and traders, including wholesalers, retailers and input dealers) with different world views were involved so that any proposed management interventions were informed by a breadth of available experience and thereby acceptable to those who would have to implement the changes or live with the consequences of their implementation. The iterative process serves as a valuable informal co-learning experience and leads to new levels of capability and performance. Working as a coalition in this way is the most effective way to

deal with complex issues, as the methodologies and processes acknowledge that complex problems are multidimensional and must involve all stakeholders. They require cross-sectoral communication and collaborative approaches to resolve and deal with the many uncertainties that require adaptive management approaches as more knowledge becomes available through the iterative process of learning by doing.

By combining a broad range of tools and techniques developed in the field of systems thinking, using the Evolutionary Learning Laboratory (ELLab) framework, various stakeholders in the agriculture industry deliberated on the issues affecting sustainable agribusiness operations through a series of workshops to aid systemic interventions to overcome the challenges. The same stakeholders were also used for data validation.

The ELLab enhances the bottom-up approach in which stakeholders participate in solving their management problems themselves, instead of bringing in outside experts to do so (Bosch et al. 2013). Systems thinking helps in the identification of the root causes of agricultural management problems and highlights the potential implications of policy decisions by identifying both the individual factors that may affect an outcome and the causal relationships between them.

The ELLab framework and the BBN process involve identifying leverage points and setting management objectives respectively, abstract modelling to explore the effects of decisions or scenarios on management objectives, developing plans for implementing preferred interventions, monitoring the system to track management successes and reflecting on management interventions where necessary. As no systems model can ever be completely 'correct' in a complex and uncertain world, the only way to manage complexity is by regularly reflecting on the outcomes of the actions and decisions that have been taken in order to determine whether the interventions are successful and to identify significant unintended consequences and new barriers that were previously unforeseen. This research focuses on the first five steps of the ELLab framework, which are detailed in each paper in the chapters that follow.

1.5 Scope and Limitations

Systems thinking is a transdisciplinary 'framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots' (Nguyen & Bosch 2012). Therefore, systems thinkers frame a problem in terms of seeing the whole forest instead of focusing on a particular tree. They see beyond the details to the context of the relationships in which they are embedded (Sherwood 2002). Today, systems thinking is used by academics and practitioners alike to address sustainability challenges. Systems thinking as a generic

approach has been applied in natural resource management, environmental conflict management, community development, business, health, agricultural production systems, education, decision making, human resource management, innovation, social theory and management, food security, and population policy (Nguyen & Bosch 2012, p. 105). The empirical model and its application are framed in the context of systems thinking using CLD models and BBN modelling to manage complex challenges.

However, as with any new problem-solving approach, the systems approach has received criticism. There is an assumption that systems thinking is too fundamentalist, 'epitomizing an essentially technocratic view of business problems' (Kim 2012a). Its dependency on models and its lack of solutions threatens its legitimacy in corporate boardrooms and management education. Walter and Stützel (2009) approach the sustainability of land use systems with a new method. Unlike Nguyen and Bosch (2012), these authors seem to take a more negative view of participatory stakeholder involement, which they claim (with little evidence) is not always practicable due to high cost and time, and its outcome may be biased.

Nevertheless, it is natural to approach problems first by diagnosing the problem in order to figure out how to fix it, and then by implementing solutions with known outcomes. Thus, systems thinking is necessary for sustainability challenges. According to Stowell and Welch (2012) and Checkland (2000), tackling the ill-structured problems of the physical world involves close involvement of stakeholders and researchers to resolve complex organisational situations. Stakeholders often disagree over the actions and policies needed to achieve sustainable management goals. Systems thinking provides a mechanism for identifying the root causes of sustainable management problems and, when combined with stakeholder participation, it assists in creating a common understanding among stakeholders about these causes and the actions and policies needed to tackle them. In the long run, stakeholders take ownership of the solution, which ensures adoption and implementation because it is their own mental model. This is the scientific relevance of the ELLab approach, and it has been used in several studies. For example, Bosch et al. (2013) used it to unravel complexity through participatory systems analysis, and Nguyen, Bosch and Maani (2011) used it to determine the components and interactions between the policy, social, environmental and economic dimensions of the CBBR in Vietnam. Further, it has been used to develop systems maps for leverage points identification in complex systems (Banson & Egyir-Yawson 2014; Banson et al. 2015; Nguyen, Bosch, Banson et al. 2014). The research processes include generic skills in problem solving, team participation and team learning.

The practical limitation is that it requires time to refine the model, which reveals the structure of the system and makes it possible to ascertain a system's behaviour over a certain period.

The limitations associated with complex BBN (large probability tables and dilution of the influence) means that the range of critical interventions believed to influence the objectives must be summarised into as few 'nodes' and 'states' as possible. Thus, all factors mentioned by stakeholders cannot be captured into the models. This study agrees with Nguyen and Bosch (2012), who highlight and address the challenges of an integrated approach by applying a systems thinking model that demonstrates how to translate hitherto difficult ideas into potent management tools for change. The theory of their approach is illuminated by thoughtful, realistic examples to enhance the readers' understanding of not only when a more systemic solution is possible, but also how to uncover that solution. Systems thinking not only offers a language for understanding complexity and dynamic change, but it also provides sophisticated modelling technology and associated collaborative learning environments. In addition, systems thinking tools such as BBNs are a flexible and visual system modelling tool that are capable of integrating qualitative and quantitative data and accommodating uncertainty. Combined with their scenario and diagnostic capabilities, this makes them well suited for use in participatory systems analysis activities.

1.6 Significance to Discipline

Systems thinking tools provide a conceptual framework and a methodical process that can be used to achieve outcomes that may contribute to the development of sustainable systems. The use of a systems thinking approach in applied economics in the context of a social, economic, environment or business has significantly increased in modern times (Nguyen & Bosch 2012). The increasingly complex nature of government and business has led to increased use of a systemic research approach to solve operational problems. This assumes a significant role in the formulation of economic policy for both the government and business. This approach is a new concept in sustainable management, and its application to agricultural sustainability management is yet to be exploited by many researchers, managers and policymakers in Africa. Other generalist thinking or traditional approaches have been attempted to solve problems in isolation in sustainability management, but with little success. However, this approach highlights and addresses problems in integrated or systemic approaches and demonstrates how to translate hitherto difficult ideas into potent management tools for change. The theory of this approach uses thoughtful, realistic examples to build policymakers' and/or managers' understanding of not only when a more systemic solution is possible, but also how to uncover that solution.

The results can be applied to a wide range of situations because the approach is adaptable to different contexts and can deal with complexity, as in Ghana's agricultural sector. This research will benefit not only Ghana and several other countries in Africa, but also the world

at large. First, the study will benefit governments, managers, policymakers in agricultural sectors, the World Bank, the Food and Agriculture Organization of the United Nations (FAO), non-government organisations (NGOs) and other development agencies, as the model can reveal the root cause of challenges and identify key leverage points. It could also serve as the basis of an economic system for all governments and proponents of good policies for sustainability. Further, it can be used as a 'simulation model' to develop and test alternative government budget formulations and management policies, which helps to properly allocate a country's scarce resources. The approach of this research can serve as a platform to work with the complexity of the challenges in natural resource management in addition to social, economic and environmental development in Ghana. This research aims to bridge the gap between dealing with problems in isolation and an integrated approach.

In this light, the results (CLD) of this study seek to reveal and foster integrated planning for sustainable development, which is nessesary in Ghana, and to avoid disjointed government policies coupled with a lack of unity in fixing challenges among international agencies. The model will also help decision makers anticipate the long-term consequences of their decisions and actions, as well as avoid significant unintended consequences of policies and strategies. The methodology will provide deep dialogue and consensus building with a common language for diverse stakeholders.

1.7 Linkages of Published Papers

These papers focus on the application of the ELLab framework and BBNs as knowledge integration tools in sustainable agricultural management and decision making. The ELLab is designed to equip policymakers, researchers and all relevant stakeholders with a new way of 'thinking' that moves away from the traditional 'linear' approach of problem solving and towards a holistic systems approach that focuses on the root causes and interconnectedness between various components of the agricultural system. The BBN is used after the identification of the leverage points from the CLD designed as a result of the ELLab process. The BBN decision-making approach involves stakeholders participating in solving management problems using systems thinking to identify and relate factors that may affect management objectives. The process involves setting management objectives, abstract modelling to explore the effect of decisions on these objectives, identifying preferred management interventions, and monitoring to track the success of implemented management interventions.

Paper 1 investigates the pressing constraints and challenges facing the complex agricultural system in Africa. Causal loop and BBN modelling are used to develop systems models to determine the components and interactions between the policy and the social, environmental

and economic dimensions of the industry. Insights into potential system behaviours and leverage points for the systemic interventions required for sustainable agricultural development are identified.

Paper 2 examines the SCP of the agricultural sector in a case study in Ghana. It illustrates how the SCP elements interact together to influence the survival and growth of the agricultural sector.

Paper 3 uses systems archetypes to analyse current policies and stakeholders' opinions concerning how the agricultural system works, the barriers to success and the system drivers. System archetypes are applied as diagnostic tools to anticipate potential problems and problem symptoms. Eleven system archetypes serve as the means for gaining insights into the underlying system structures from which the archetypal behaviours emerge. As part of a suite of tools, they are extremely valuable in developing broad understandings about agriculture and the environments, and they contribute to more effectively understanding the cause of a fix 'now' that gives rise to a much bigger problem to fix 'later'.

Paper 4 reports on the employment of a systems thinking approach and the use of various systems tools to address sustainability constraints and the challenges affecting the performance of the agricultural sectors in Ghana. It provides possible new strategies or solutions that need to be designed to overcome these problems in the agricultural sector of Africa, including Ghana. It is a direct follow-up to the publication of Banson et al. (2015), which identified the pressing constraints facing stakeholders and the performance of the agricultural sector in Africa, including Ghana.

Paper 5 examines how competitiveness can be increased through the proper allocation of a country's scarce resources. This research employs systems thinking tools for the establishment of a community development model, the 'Greater Push' and a new way of measuring, monitoring and evaluating sustainable development with BBN modelling that satisfies the 'Bellagio Principles' for measuring sustainable development indicators.

Chapter 2: Paper One: Systemic Interventions for African Agriculture

■ Research Paper

A Systems Thinking Approach to Address the Complexity of Agribusiness for Sustainable Development in Africa: A Case Study in Ghana

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African countries have comparative advantages in the production and export of primary commodities; however, they face many sustainability challenges in the agricultural sector. Since the democratization of many African countries, notably Ghana, there have been a number of interventions costing billions of dollars to overcome the challenges facing the agricultural industry but with little success. The agricultural industry is a complex system. Causal loop and Bayesian belief network modelling were used to develop systems models to determine the components and interactions between the policy and the social, environmental and economic dimensions of the industry. Insights into potential system behaviors and leverage points for systemic interventions required for sustainable agricultural development were identified. The systems models will help governments to anticipate the long-term consequences of their decisions and actions, as well as help to avoid any unintended consequences of policies and strategies such as 'silo mentality' and 'organizational myopia'. Copyright © 2014 John Wiley & Sons, Ltd.

Keywords: Sustainable agricultural development; complexity; systems thinking; decision making; Africa

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Overall percentage (%)	85%
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
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Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

    i.   the candidate's stated contribution to the publication is accurate (as detailed above);

    ii.   permission is granted for the candidate to include the publication in the thesis; and

    iii.   the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Contribution to the Paper   Editing and co-authoring the manuscript.

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2.1 Introduction

2.1.1 Economic Importance of Agriculture to the Economies of African Countries

Increasing the production and export of agricultural products in a sustainable manner could be an effective way of reducing poverty and enhancing economic growth in developing countries. Agriculture is the backbone of most African economies. It also has comparative advantages in the production and export of primary commodities in addition to timber, minerals and oil (Bates 2005; Nutsukpo et al. 2012). In addition to being an important source of household income, it also constitutes the core of raw materials for the manufacturing sector. Africa is populated with more than 900 million people, and 70% of them are engaged in agriculture for full-time employment (Bationo & Waswa 2011; Mahajan 2009; Ojukwu et al. 2010). Agriculture also accounts for 33% of national income and 40% of total export earnings (Bationo & Waswa 2011), and many people also depend on agriculture for part of their household income. Given the importance of the agricultural sector to the national economy and household income, accelerating agricultural growth is a key to transforming Africa and reaching the middle-income country target (Bates 2005; Breisinger et al. 2008).

Despite the importance of agriculture in the African economy, it is characterised by low productivity, poor-quality products, poor service quality, and high production and transaction costs (Eifert, Gelb & Ramachandran 2008; Kydd et al. 2004; Wiebe et al. 2003). Some countries in Africa continue to have extreme cases of famine, which may be caused by crop failure, population unbalance or government policies (Devereux 2009). This phenomenon is usually accompanied or followed by low yields and productivity, regional malnutrition, starvation, epidemics and increased mortality. Coupled with international trade, the demands for a particular variety of crop have tended to favour non-traditional varieties, which have come to dominate agricultural production, processing and commerce (Banson & Danso 2013). The demands for research, and hence funding, have inevitably concentrated on these commodities. Africans often produce what they do not consume and consume what they do not produce. Little or no attempt is made to improve some of Africans' indigenous traditional varieties (Banson & Danso 2013).

Changes in the world's climate have also contributed to major shifts in food production in Africa. In some places, temperatures have risen and rainfall has increased; in other places, rainfall has decreased (Barrios et al. 2006). In addition, coastal flooding has reduced the amount of land available for agriculture. In general, food crops are sensitive to climate change. Such changes, which affect soil temperature and moisture levels, also determine the vitality of both beneficial organisms and pests.

The agricultural sector is also plagued by major environmental constraints such as competition, legal requirements and technology such as deadly chemicals and heavy farm machinery compacting farm soils (Bationo & Waswa 2011; Nutsukpo et al. 2012; Ortmann 2000, 2005). Human factors that affect food prices and people's ability to afford food despite its availability also trigger acute hunger episodes in Africa. An important factor driving increased hunger in Africa today relates to the free market. Markets in Africa have been opened up to the global food supply relative to the European Union (EU) and United States (US), which have pursued free market conditions to create competition and new markets. This direct connection with EU and US subsidised food supplies have worsened the plight of African farmers. First, cheaper food imports undermine local food production and reduce domestic support, making it difficult for local farmers to compete on prices. This leads to smaller incomes and increased food insecurity. Second, global food supplies are volatile to price changes based on global conditions. The trade in food as a commodity leaves African people more at risk to food shortages as prices increase. Increases in food prices therefore have a more immediate and damaging effect on food security in African countries.

Over the past 20 years, there has been an average increase in agricultural production of 3.2% due to an increase in land under cultivation rather than an increase in productivity. For example, an increase of 229% in cultivated farmland accounts for only a 70% increase in productivity in regional production (Oxford Business Group 2010). The average agriculture growth rate in real terms has been stagnant at about 1.7% to 1.9% since 1965 (Cleaver 1993). According to Cleaver (1993), the agricultural growth rate is far lower than the population growth rate, which has increased from 2.7% per annum between 1965 to 1980 to 3.1% per annum since the 1980s. These and other significant factors have exposed 200 million people in Africa to the vulnerability of food insecurity (Ojukwu et al. 2010). This is further demonstrated by food imports and aid, which have increased by 4% and 7% per annum respectively since 1974 (Cleaver 1993) and have placed more pressure on economic growth, which has been steady at 3% for the past 20 years (Ojukwu et al. 2010). Currently, it is estimated that Africa will be able to feed less than half of its population from domestic agricultural production by 2018 (Ojukwu et al. 2010). Agricultural GDP per farmer over the past two decades has risen by less than 1% in Africa relative to 2% and 3% per annum in Asia and Latin America respectively (Nutsukpo et al. 2012; Ojukwu et al. 2010). According to Boko et al. (2007), there has been a 20% to 40% decline in rainfall in Africa over the past 50 years, which has resulted in serious drought consequences for the savanna or dry land areas. Per-hectare yields for most crops are among the lowest in the world, only increasing by an average of 42% between 1980 and 2005, and accounting for just 30% of the increase in agricultural and food production (Bationo & Waswa 2011).

These factors have been the mainstay of African societies engaging in subsistence agriculture since the dawn of agriculture itself. Given these factors, the main concern of African governments and other authorities is to prevent famine and ensure timely food supplies. Most governments are severely limited in their options because of limited levels of external trade, poor infrastructure and rudimentary bureaucracy. Despite many initiatives to address and modernise the agricultural sector in Africa, most of them have failed to achieve their objectives because of the challenges of low agricultural productivity, abject poverty, food shortages, unequal income distribution, deforestation and unfair competition. These challenges continue to hamper the development of the sector.

2.1.2 Past Initiatives to Modernise the Sector

According to Sandrey et al. (2008) and Vink, Tregurtha and Kirsten (2002), as cited in the Economic Research Division (2011), the agricultural sector has undergone significant economic, social and political changes since the beginning of African democratisation in the twentieth century. This has increasingly affected productivity and the progress of integration into world markets. The World Bank, FAO, governments, research institutions and NGOs have implemented many initiatives to address and modernise the agricultural sector in Africa. Since 1972, the World Bank has addressed the challenges facing agricultural industries in developing countries through the Consultative Group for International Agricultural Research. In 1975, the World Bank published 'Rural Development in Africa', which was the centrepiece for the bank's initiatives to counteract food shortages and unequal income distribution (World Bank 2013b). In 1978, the World Bank investigated ways to alleviate abject poverty and distribute the benefits of growth to the poorest people. In the same year, the World Bank and the International Fund for Agricultural Development (IFAD) signed an agreement to cooperate in the identification, preparation, appraisal and administration of agricultural development projects. In 1979, former president of the World Bank, Robert McNamara, warned that the growing trend towards trade protectionism could undermine economic development. He proposed 'structural adjustment' lending in an address to the United Nations Conference on Trade and Development in Manila, Philippines (World Bank 2013b).

In 1981, the World Bank focused on an agenda for action, also known as the 'Berg Report', for accelerated development in Sub-Saharan Africa. Then in January 1985, the World Bank donated $3 million to the World Food Program to provide emergency food supplies to drought-stricken Sub-Saharan Africa. This was the second donation within the space of 12 months ($2 million was granted in April 1984). Donors responded to these difficult problems by increasing aid flows to the point where African countries now lead the list of the world's aid recipients in per capita terms. After more than two decades of rising commercial food

imports and food aid (Program Food Aid, Relief/Emergency Food Aid, Project Food Aid), the region is now experiencing a deep economic malaise, with growing balance-of-payments deficits and external public debt. This indicates that the initial World Bank intervention gave rise to a much larger problem, and their approach could not fortify the sector.

In 1986, the World Bank issued a statement regarding its forestry operations. The statement asserted that the Bank was deeply concerned about the destruction of tropical forests and was intensifying efforts to effectively deal with the problem. In 1996, the World Bank published 'Taking Action to Reduce Poverty in Sub-Saharan Africa', which outlined specific actions that the Bank planned to take to improve results in poverty alleviation. In 1998, the World Bank and the African Development Bank held a meeting of African agricultural policymakers and researchers in Abidjan, Ivory Coast, to discuss food security and economic growth. In 1999, the World Bank approved a program for policy-based guarantees, extending the Bank's existing partial credit guarantee instrument beyond projects to include sovereign borrowings in support of structural and social policies and reforms. Previous new lending instruments, including Learning and Innovation Loans, Adaptable Program Loans, Programmatic Structural Adjustment Loans and Special Structural Adjustment Loans, failed to deliver on their promises (Havnevik et al. 2007).

In the 1990s, African heads of state, governments and donors engaged in a variety of tentative initiatives to reverse the negative trends concerning agriculture in Sub-Saharan Africa (Zimmermann et al. 2009). In 2003, NEPAD and CAADP were launched to catalyse agricultural growth in the region (Zimmermann et al. 2009). Further, in 2003, African governments signed the Maputo Declaration, committing to a minimum allocation of 10% of their national annual budgets to agriculture (African Union 2003). Recent political fora have confirmed the urgent need to secure and increase basic food staples. These include the Sirte Conference on Water for Agriculture and Energy (December 2008), the FAO of the United Nations Summit (2008) and the African Union Summit (July 2009) on Investing in Agriculture for Economic Growth and Food Security (African Union 2009; FAO 2008). As an expression of their strong commitment to support agriculture in Africa, in July 2009, the G8 pledged to provide $20 billion over the next three years to increase food production on the continent (Zimmermann et al. 2009). The L'Aquila Declaration, which centres on energy and climate, further underscores the need for the effective use of investments in the agricultural sector (Zimmermann et al. 2009).

The prospects for meeting Africa's food production deficit through aids thus appear dismal. Donors often have a vested interest in the recipient country expanding and gaining more power in regions where policies are implemented in their favour. For instance, the supply of

food aid to poor countries creates new markets for donors to sell their products, which then strengthens their exports. However, it also weakens the recipient country because money flows out of the country, thereby encouraging increased consumption of cheap imports and resulting in the undermining of local agriculture, thus driving 'non-competitive' farmers out of agriculture and increasing food insecurity, hunger and poverty.

It is clear from the above discussion that the challenges in Africa are complex. To help address these issues, there is a need to equip policymakers, researchers and all relevant stakeholders with a new way of 'thinking' in order to move away from the traditional 'linear' approach to solving problems and towards a holistic systems approach that focuses on the root causes and interconnectedness between various components of the agricultural sector.

2.2 Systemic Approach to Sustainable Agriculture in Africa

African governments and agriculture proponents currently have neither adequate information nor the necessary tools required to analyse the performance of policies affecting the food and agricultural sectors. They are under increasing pressure from the people they govern to make the right management decisions in the face of a continually changing political and socioeconomic landscape. The local and global challenges currently facing the agricultural sector of Africa (including Ghana) are highly complex in nature. As shown by past interventions, these challenges cannot be solved in isolation and with single-dimensional mindsets and tools. Traditional approaches or analysis, which study systems by breaking them down into their separate elements to solve problems, have been attempted with little success. However, the systems thinking approach highlights and addresses problems using integrated or systemic approaches and demonstrates how to translate hitherto difficult ideas into potent management tools for change. The increasingly complex nature of government and business has necessitated the use of a systemic research approach to solve operational problems. This assumes a significant role in the formulation of economic policy for both government and business. This approach is a new concept for sustainable management, and its application to agricultural sustainability management is yet to be exploited by many researchers, managers and policymakers in Africa. Agricultural sustainability may benefit from a systemic approach to interventions and capacity-building based on systems thinking and complexity management to address challenges holistically and deliver the desirable sustainable outcomes. The ongoing CBBR sustainability project in Vietnam (Bosch et al. 2013; Nguyen & Bosch 2013) is a demonstration case for these approaches, and its principles and lessons can be applied to the agricultural sector.

The systems thinking approach is a transdisciplinary framework that addresses the root causes of challenges by viewing problems as parts of an overall system, in contrast to the linear approach of identifying 'quick fixes' to specific parts. This leads to the danger of 'silo mentality', in which a fix 'here' simply shifts the problem 'there', and 'organisational myopia', in which a fix 'now' gives rise to a much bigger problem to fix 'later' (Nguyen & Bosch 2013; Sherwood 2002). Therefore, systems thinkers frame a problem in terms of seeing the whole forest instead of focusing on a particular tree. They see beyond the details to the context of the relationships in which they are embedded (Sherwood 2002). Today, this approach is widely used by academics and practitioners alike to address sustainability challenges. The application of systems thinking as a generic approach has been evidenced in many fields and disciplines, including natural resources, human resources, innovation, social theory and environmental conflict management, community development, business, health, agricultural production systems, education, decision making, food security, and population policy (Nguyen & Bosch 2013). In systems thinking, an alteration in one area of a system component can adversely affect another part of the system; thus, it promotes self-organisation and emergence at all levels. That is, the system acts to keeps its internal equilibrium in order to avoid the silo effect.

According to Nguyen and Bosch (2013), systems thinking is a way for professionals to conceptualise and move towards the integration of social, environmental and economic dimensions of sustainability. This helps communities to address the challenges of improving the wellbeing of both humans and the ecosystem. Bosch et al. (2013) agree that the systems thinking approach supports the management of complexity more effectively than other approaches. The challenges of sustainability are complex and ever-changing, and they require the development of effective mental models in the face of rapid social, political, economic and technological changes that support an adaptive transition to sustainability. Senge (1997) explains that mental models are deep-rooted generalizations, or images that influence how we understand the world and how we take action. Mental models exist for families, organisations, the global market and the environment, and in our concepts of what sustainability is and how to achieve it (Soderquist & Overakker 2010). Mental models are used to develop an understanding of what a system looks like. CLDs are a useful tool for integrating and interpreting stakeholders' mental models.

CLDs consist of variables that are connected by key causal relationships to represent reality, and they can be used to display cause-and-effect behaviour from a systems viewpoint (Toole 2005). CLDs simply convert complex elements into a simple, easy-to-understand format. The relationships between these variables (represented by the arrows in Figure 2.1) can be labelled positive or negative. Reinforcing feedback is when changes in the elements of the system are fed back and result in an amplification of the change. Balancing feedback is when changes in the elements of the system are fed back and oppose the original change, resulting in a counteracting effect.
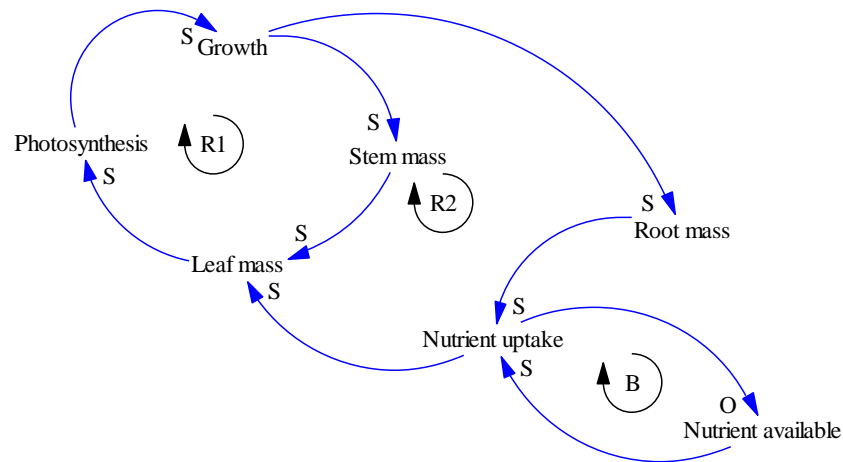
Figure 2.1: Photosynthesis loop

Everything starts with a cause, which leads to an effect, then another cause, and then another effect, thereby forming a network of interactions, or a systems model. If the cause and effect change in the same direction, the symbol '+' or 'S' is used. In contrast, if the cause and effect change in the opposite direction, '–' or 'O' is used. Feedback loops describe the cause-and-effect relationships between the parts of a system (Bettis & Prahalad 1995). For example, plants photosynthesise to grow. When they grow larger, they require more photosynthesis, so there will be another positive side, which demonstrates reinforcing feedback (see Figure 2.1). Better growth enhances the size of the stem and leaf masses, leading to more photosynthesis. This is the first reinforcing feedback (R1). Through the same process, as the plant grows, it enhances the root mass, which encourages more nutrients to be absorbed. The leaf mass gets stronger and more photosynthesis is required, resulting in the second reinforcing feedback (R2). In contrast, as more nutrients are taken up, fewer nutrients are available in the soil, resulting in a balancing feedback loop (B).

In this research, systems models are developed to provide an understanding of the dynamics, interconnectedness and relationships present within the agricultural industry. The research uses a systems-based ELLab (Bosch et al. 2013) approach to identify and effectively address complex sustainability issues affecting the agricultural industry in Africa.

2.3 Approach and Discussion

The ELLab (see Figure 2.2) is a unique 'methodology' or approach that holistically integrates a system's constituent parts and uses existing and new knowledge to help manage complex issues progressively (Bosch et al. 2013). This approach has been successfully used to address complex issues in a variety of contexts (Bosch et al. 2013; Nguyen & Bosch 2013).
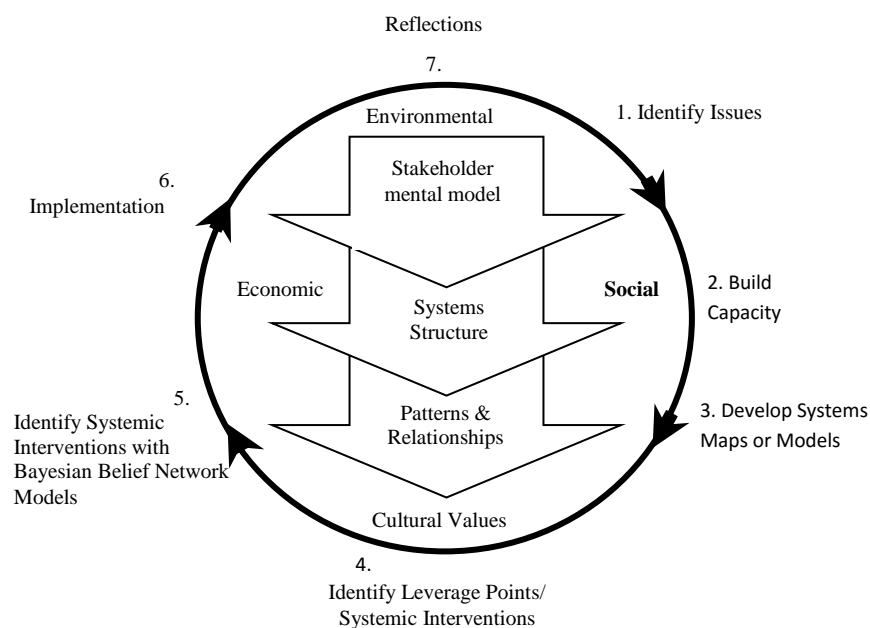
Figure 2.2: Basis of the systemic approach for managing complex issues (adapted from Bosch et al. 2013)

In this study, the application of the ELLAB commenced by gathering the mental models of all stakeholders involved (step 1). Their opinions and perceptions of how the system works, the barriers to success, the system drivers and possible strategies (solutions) to overcome these problems were obtained through an in-depth literature study and focus group discussions with a group of agricultural experts from Africa who were studying at the University of Adelaide, South Australia. Step 2 was conducted through follow-up capacity-building by involving agricultural PhD students at the University of Adelaide from African countries to integrate the various mental models to fit the systems structure. The Vensim software program (Ventana Systems UK) was used to develop the CLDs of the issues under consideration. Step 3 was completed by interpreting and exploring the models for patterns in their interconnected components, and by analysing the reinforcing and balancing feedback loops. In step 4, the

leverage points for systemic intervention were identified. Leverage points are places within a complex system (e.g., agricultural industry or ecosystem) where a small shift can generate a bigger change in the whole system, which can lead to significant lasting improvements (Bosch et al. 2013; Nguyen, Bosch & Maani 2011). In step 5, the outcomes were used to develop a refined systems model, which constitutes an integrated master plan with orderly defined goals and strategies (systemic interventions). To operationalise the master plan, BBN modelling (Bosch et al. 2013; Cain, Batchelor & Waughray 1999; Smith, Felderhof & Bosch 2007) was used to determine the requirements for the implementation of the management strategies, the factors that could affect the expected outcomes and the order in which the activities should be carried out to ensure cost effectiveness and to maximise effect.

The systems model was used as a simulation model to test the possible outcomes of different systemic interventions by observing what would happen to the system as a whole when a particular strategy or combination of strategies was implemented—that is, before any time or money was invested in implementation. According to Bosch et al. (2013) and Braun (2002a), this is a prospective tool that alerts managers to foresee some of the future unintended consequences by making time an explicit variable in decision making to ensure a cost-effective plan of action.

Once the systemic interventions have been identified and an operational plan has been developed, the strategies are implemented. This step is yet to be applied in this study, as only the systems tools of the ELLab were used to analyse and interpret the agricultural system. As no systems model can ever be completely 'correct' in a complex and uncertain world, the only way to manage complexity is by regularly reflecting on the outcomes of the actions and decisions that have been taken to determine whether the interventions are successful and to identify significant unintended consequences and new barriers that were previously unforeseen (Bosch et al. 2013).

2.4 Key Variables of the Agricultural Sector in Africa

A number of key variables in the agricultural sector of Africa were identified through a series of focus group discussions and an in-depth review of literature. These variables are organised into four main categories: Ministry of Food and Agriculture (MOFA), quality, export and agribusiness (see Table 2.1).

Using the CLD modelling approach led to the formation of four interrelated loops for the sector: MOFA, quality, export and African agribusiness industry.

Table 2.1: Key variables of the agricultural sector of Africa

MOFA	Quality	Export	Agribusiness
Extension service	Cost	Regulations	Budget to Agriculture
Extension capacity	Produce quality	Market share	Profit
Training	Willingness to pay	Market size	R&D
Workload	Regulation	Exporter	Training
Strain on MOFA	Strain on export	Customer	Youth in agriculture
Cost	Exporter revenue	Farm scale	Migration
Ability to cope with farmers issues	Extension service quality	New farmers or exporters	Good Agricultural Practices
Extension officers head count	Exporter dissatisfaction	GDP	Environmental protection
Farmer population	Farmer revenue	Agronomic issues	Productivity
Farmer problems	Margin	Sales revenue	Savings
Farmer error	Resource	Profit	Seeds
Extension monitoring device	Frustration	Returns to investment	Yields
Farmer load	Migration	Investment	Storage facilities
Agriculture policy	Infrastructures	Competition	Value addition
Agricultural capacity	Storage facilities	Contract	Returns
Economic prosperity	Quality seed	Conflict	Deforestation
Education	Productivity	Employment	Co2 emission
Employment	Quality control	Growth rate	Pollution
Growth rate	Production cost	Farmer load	Health
Land reforms	Resource capacity	Price	Access to finance
Famine	Farmer load	Farm income	Climate change adaption
Food security	Pest	Hunger	Hunger
Agricultural development	Smallholders	Exchange rate	Poverty
Adoption	Innovation	Economy of scale	Household
Farmer organisation	Farming system	Protectionism	Fuel
Information	Price	Irrigation	Expenditure

Sources: Focus group discussions of experts from Africa (Anderson & Feder 2004; Barrows & Roth 1990; Bautista & Valdés 1993; Coulter & Onumah 2002; Delgado 1998; Delgado & Mellor 1984; Gibbon, Havnevik & Hermele 1993; Godfray et al. 2010; Haug 1999; Morris 1976; Pretty 1999; Pretty, Toulmin & Williams 2011; Raikes & Gibbon 2000; Viljoen 2005; Vlek 1990; Wu 2004)
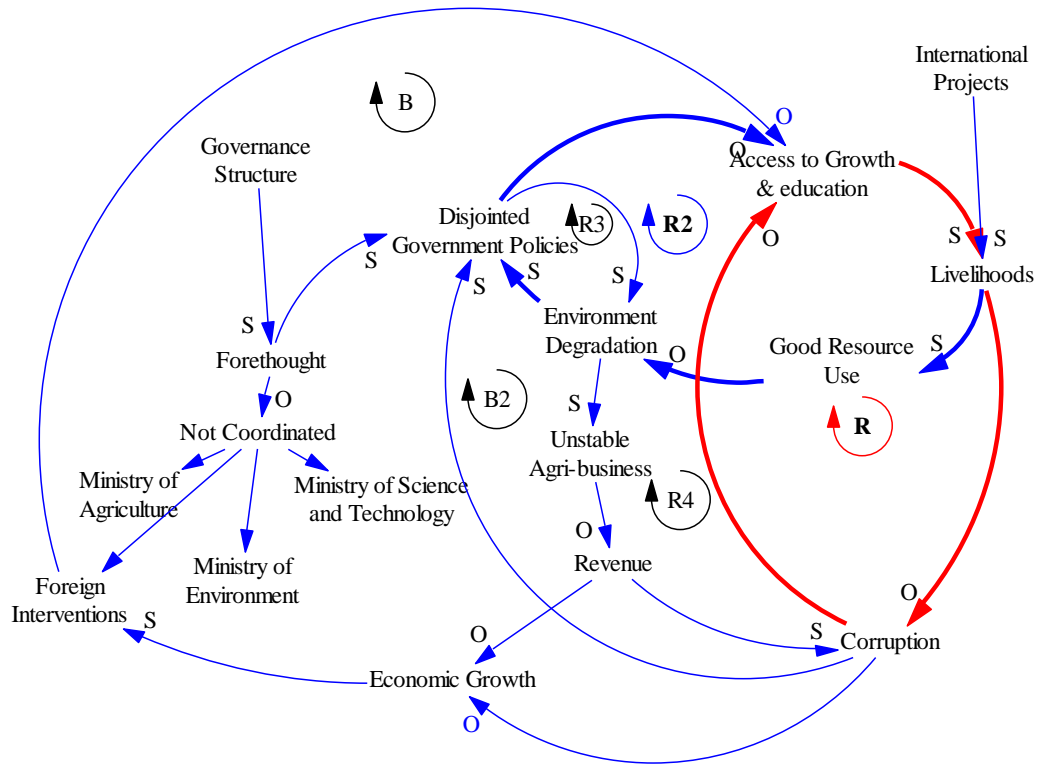
Figure 2.3: Africa's agribusiness industry loop

2.4.1 Ministry of Food Agriculture and Quality Loop

The MOFA has considerable influence on food security, quality standards and the training of farmers; thus, the MOFA and quality loops were combined to generate the MOFA and quality loop as shown in Figure 2.4.

In most African countries, the ministries control and direct the affairs of the agricultural industry. They are committed to agricultural research, technology development and technology transfer, and they direct the optimisation of agriculture's role in national growth and development. Agricultural extension is part of the MOFA, with field extension officers at the bottom of the hierarchy and a minister at the top.
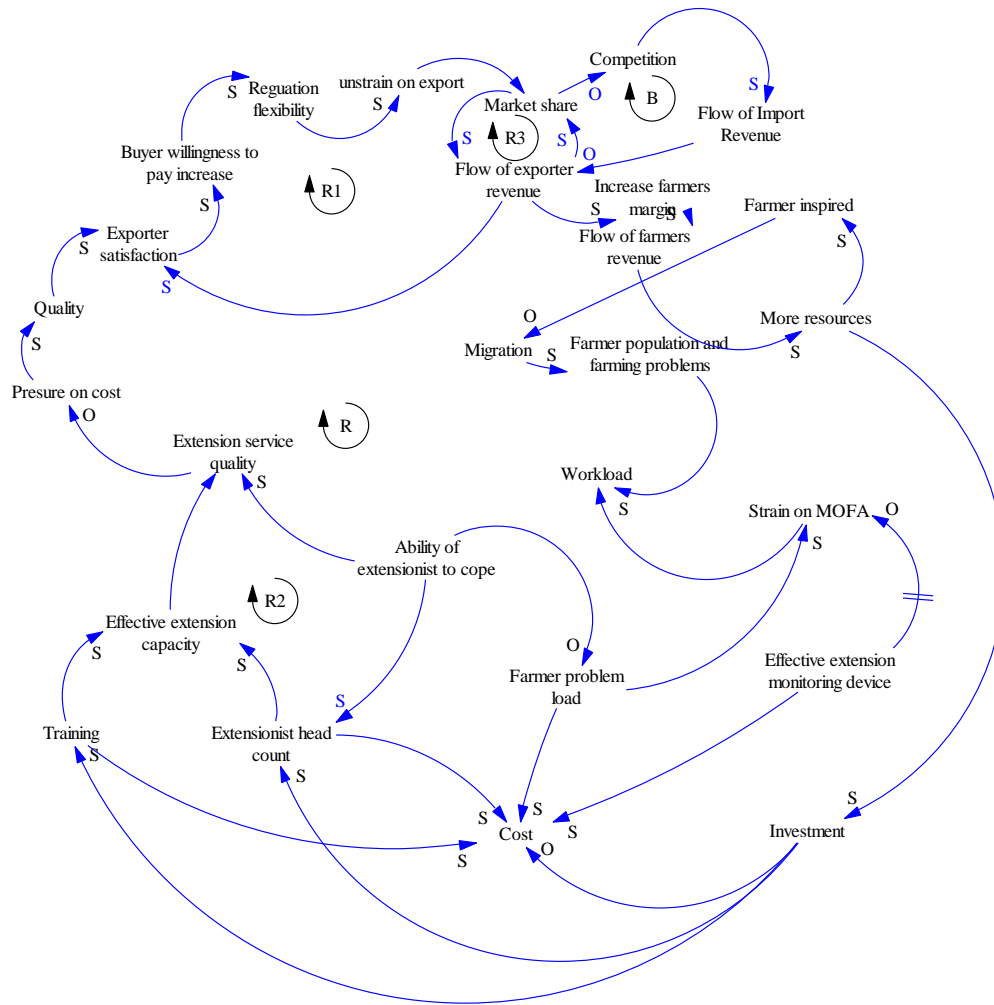
Figure 2.4: MOFA and quality loop

The centre of Figure 2.4 shows the ability of extension officers to cope and is linked to two other variables: extension service quality and farmer problem load. Agricultural extension officers are a potent and critical force in the agricultural development process. They assist farmers through training activities to improve farming techniques, increasing production efficiency and income, improving their standard of living, and lifting the social and educational standards of rural life. Agricultural extension officers also communicate agricultural research findings and recommendations to farmers and give them useful information. However, most smallholder farming operations are typified by *ad hoc*, uncoordinated individual plantings where no authorisation is required from the relevant authorities; thus, there is no record of the exact number of farmers cultivating in African countries (FAO 2004). This system has made it difficult to determine the number of extension officers that need to be deployed in a particular region to help these farmers. Therefore, the ability of agricultural extension officers to cope with farmers' problems in a particular location is an issue. The key issue for farmers is reducing production costs and not

compromising the qualities that procure buyers or customers. When product quality drops, buyers look elsewhere and farmers cannot be competitive in international markets.

An efficient extension officer should be able to cope with farmers' demands in a timely manner, including working with farmers to teach improved farming practices, new techniques and more productive or efficient technologies (R2). The MOFA and quality loop shown in Figure 2.4 demonstrates that the greater the ability to assist farmers, the better the service quality and productivity in general in the agricultural locality (R). Conversely, if the ability to assist is eroded, many things can go wrong. For example, only farmers who seek advice will benefit, and those farmers tend to be large-scale, wealthier farmers, whereas resource-poor farmers will become stressed and make more mistakes, which will eventually affect their quality and productivity (B).

According to Figure 2.4, as the ability to cope increases, so does the service quality, while the problem load of farmers decreases. As the ability of extension officers to cope decreases, farmers' problems multiply. They become frustrated, revert to trial and error, and drop out of their farming business. They migrate to cities, which in general causes productivity to decline. The direction of causality is such that, as the number of farmers increases, the extension officer's ability to cope decreases. Supervisors and managers are often drawn into the problem, collaborating with external organisations to help address the issue. This places a greater strain on the MOFA to sort out farmers' problems, and it increases their workload. The workload on the MOFA is driven by the number of farmers and the different types of agronomic problems that occur. As the numbers of farmers and agronomic problems increase, so does the MOFA's workload.

As the workload of the MOFA increases, its ability to cope decreases. To reduce strain and increase farmers' productivity, the total number of farmers must be known. This requires a system to record new farmers/exporters that enter or exit the farming businesses, the right level of extension capacity and an effective extension monitoring device. Effective extension capacity represents headcount and good training, which cost money. The 'good' of optimising the MOFA's ability to cope is therefore in direct conflict with the 'good' of minimising costs. In many instances, the budget for the agricultural sector is insufficient; moreover, in many countries, budgets have been substantially reduced or withdrawn because of structural adjustment policies. Therefore, the MOFA has imposed headcount restrictions and minimised training, and the government has diverted systems development resources to other industries in line with structural adjustment programs. However, farmers' errors are not without consequences/costs, including the cost of low productivity, the cost of losing international markets to other competitors, and the cost of correcting errors through research and

development. Conversely, if the government can meet the investment requirements of the sector, it will reduce pressure on farmers' costs and enhance the quality of produce. This will in turn increase consumers' willingness to pay, putting less strain on exports and increasing the revenues of exporters and farmers.

2.4.2 Export Loop
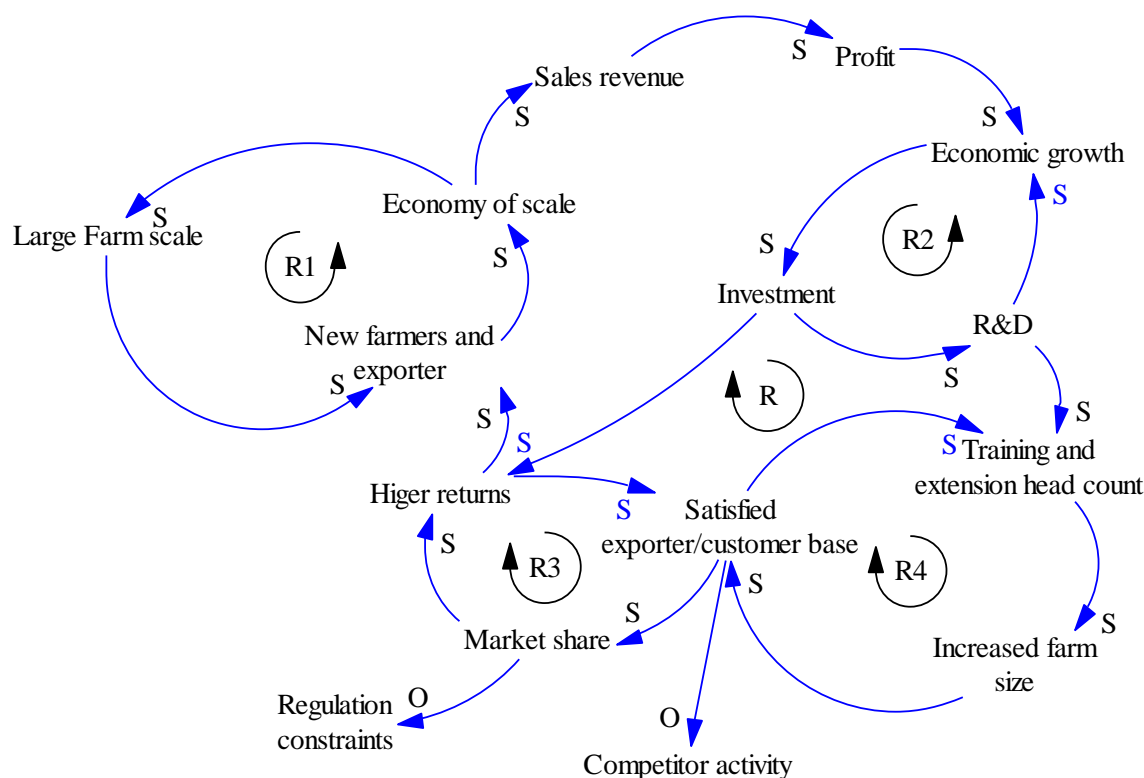
Figure 2.5: Export loop

Exporters bear the costs of compliance with international standards or related sanitary and phytosanitary rules for fresh produce exports from Africa, despite the fact that their capacity for compliance is limited. If standard measures required by importing countries are not applied to exports, the exporting country loses its market in those countries, regardless of whether it is a member of the World Trade Organization (Shafaeddin 2007). This results in major international markets' border rejections of agrifood products, and exporters bear this cost, as well as the cost of reorganising the supply chain. This often results in a lack of export expansion. However, the socioeconomic costs of a lack of compliance is enormous. Agricultural exports represent one of the most important sources of foreign exchange that ease the pressure on the balance of payments and create employment opportunities for more than 80% of the workforce in Africa. As shown in Figure 2.5, the investments of exporters in the agricultural sector leads to research and development. This enhances the knowledge of farmers and extension officers from research outcomes, which results in increased quality and efficient output, and consequently more investment in the sector. This leads to more satisfied

exporters and a customer base that increases farmers' competitiveness and market share abroad, with fewer regulation constraints. The outcome is higher returns for the actors in the field, which in turn attracts new actors to the sector, thereby increasing the nation's economy of scale of the agricultural sector and resulting in higher revenues, profits and economic development.

2.4.3 Agribusiness Loop
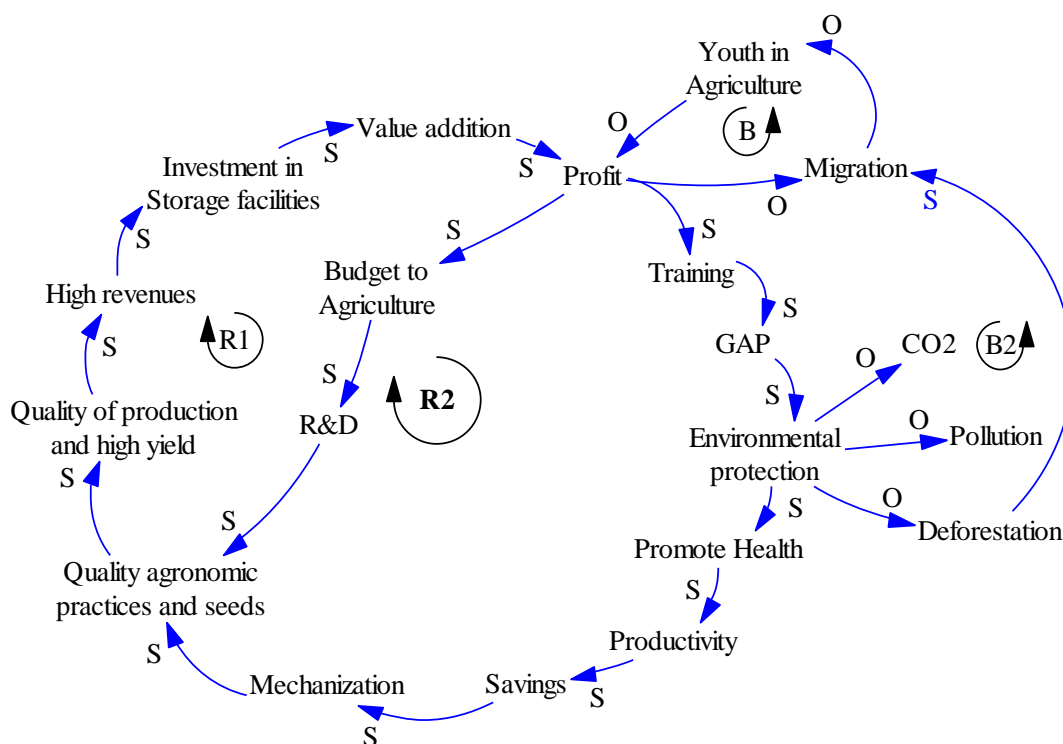
Figure 2.6: Agribusiness loop

Agribusiness contributes a major portion of GDP, employment and foreign exchange earnings in many developing countries and serves as the cornerstone of poverty reduction. In many African countries, cultivation and production of both crops and animals takes place on smallholder farms with limited mechanisation and capacity, leading to high transaction costs and poor yields. Fragmented markets, price controls and poor infrastructure also hamper production and development. Many agricultural products produced in the region, such as maize, rice and palm oil, are not competitive globally or have low profit margins. The agribusiness causal loop demonstrates that if the government increases the budget to the agricultural sector, this will increase research and development, which will in turn lead to quality agronomic practices and quality seed production. This will lead to more investment in the sector, including investment in storage facilities and semi-processing as a result of higher revenues. Increased profit will result in an increase in money circulating in the economy or investment in training. This will also attract other actors to the sector and will minimise youth migration from such sectors. Training will lead to more good agricultural practices, which

will enhance environmental protection. In the long run, this will promote good health, which in turn will increase productivity. This leads to more savings, which can be invested in many areas, including mechanisation, which also promotes quality agronomic practices, and so on.

2.4.4 Bayesian Belief Network Modelling for Improving the Quality of Export Produce

According to the MOFA and quality loop (see Figure 2.4), most African farmers face challenges in terms of product quality and food safety from dramatically changed marketing chains that require African farmers to compete in international markets. It is also evident from the above discussion that improving the quality of produce for export is a key leverage point for overcoming challenges in the agricultural industry. Subsequently, a BBN model was developed to determine the requirements of factors contributing to the improvement of export quality. A BBN model is a type of statistical model that is a graphical representation of a probabilistic dependency model in the Bayesian sense. It consists of a set of interconnected nodes, where each node represents a variable in the dependency model and the connecting links represent the causal relationships between the variables. Therefore, links have direction, from cause to effect. If there is a link from node A to node B, B is described as a child of A, and A as a parent of B. Each node may take one or a number of possible values.

The BBN Model in Figure 2.7 indicates that four conditions (market share of produce, productivity of farmers, farmers' access to information and export volumes) could enhance 'improved export quality'. These variable linkages represent conditional dependencies. Nodes that are not linked represent variables that are conditionally independent of each other. Each node is associated with a probability function that represents a possible set of values or hypotheses for the node's parent variables and gives the probability of the variable represented by the node. The structure of the BBN model and its data were developed and obtained from the literature review and the focus group discussions with experts.
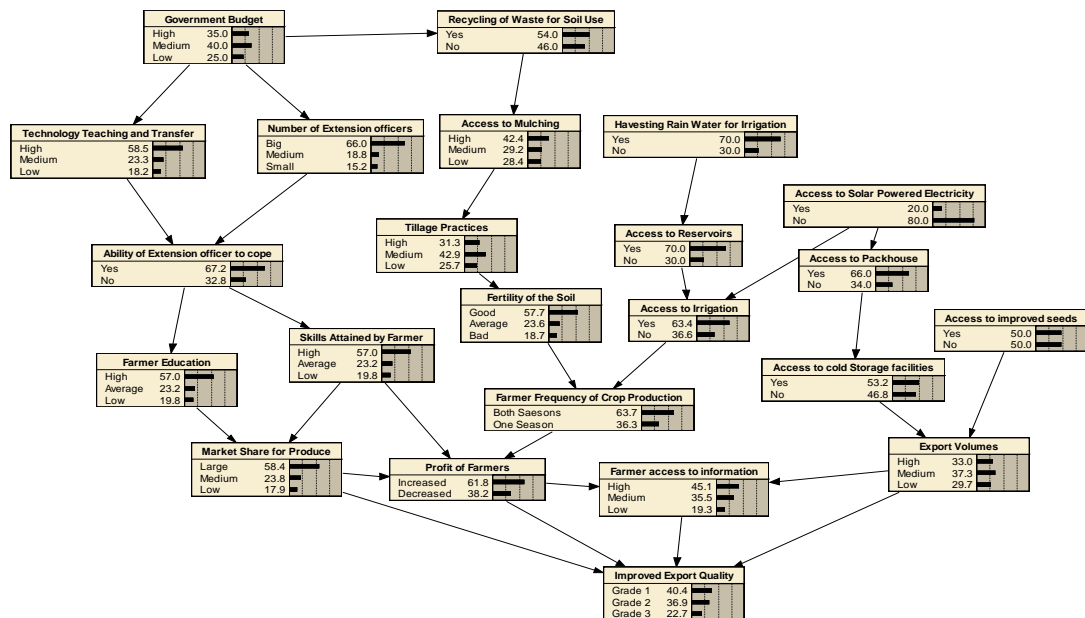
Figure 2.7: BBN modelling for quality of export produce

The BBN model, which is not yet fully functional (see Figure 2.7) indicates that the current quality levels exported from African countries are 40.4% for grade one, which is most preferred in international markets, followed by 36.9% for grade two (normally for industrial consumption) and 22.7% for grade three (local markets).
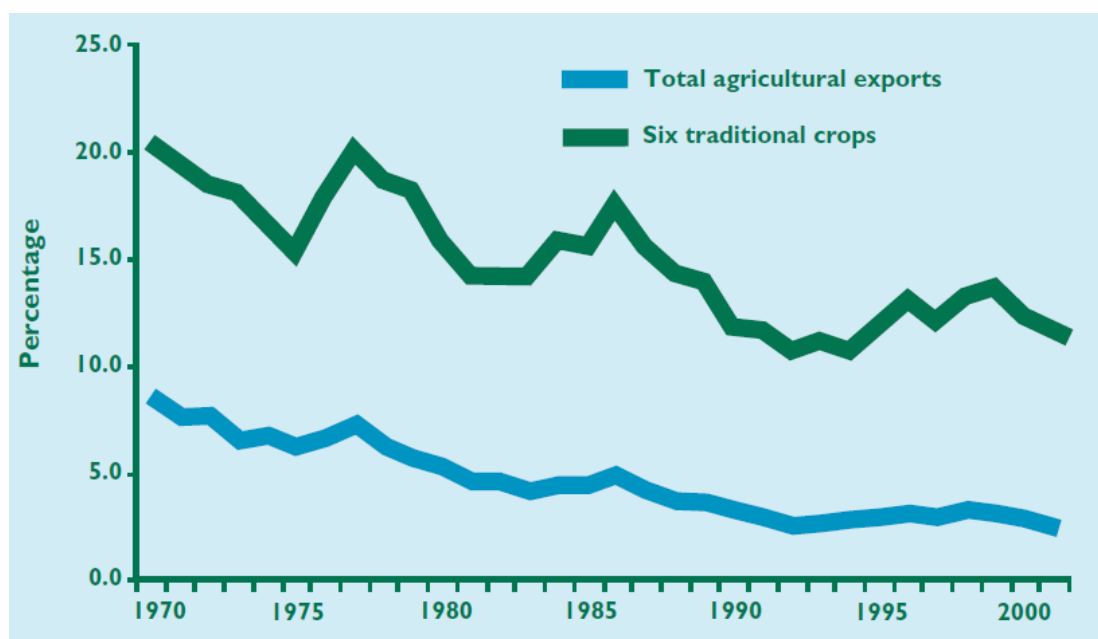
Figure 2.8: Sub-Saharan share of agricultural exports 1970–2001 (source: Diao & Hazell 2004)

The challenge posed by weak-quality produce from Africa is compounded by competition from exporters in Asia and Latin America who have improved product differentiation and quality, which are features that satisfy importing countries' increasing demands. According to Diao and Hazell (2004), Africa has lost its market share for agricultural exports in the global

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marketplace for the past two decades (see Figure 2.8). Africa's share of the total world market for agricultural exports has fallen from about 6% in the 1970s to 3% in 2013. The cultivation of traditional agricultural varieties in Africa is characterised by low yields and productivity due to environmental stresses such as droughts, pests and diseases. Coupled with international trade, demand for particular varieties of crop have tended to favour only a few major crops, which have come to dominate agricultural production, processing and commerce (Banson & Danso 2013).

The BBN model (see Figure 2.7) was used as a simulation to test the possible outcomes of different systemic interventions by observing what happens to the system as a whole when a particular strategy or combination of strategies is implemented, focusing on farmers' education, skills or experience gained by farmers, frequency of production throughout the year, and access to information (see Figure 2.9).
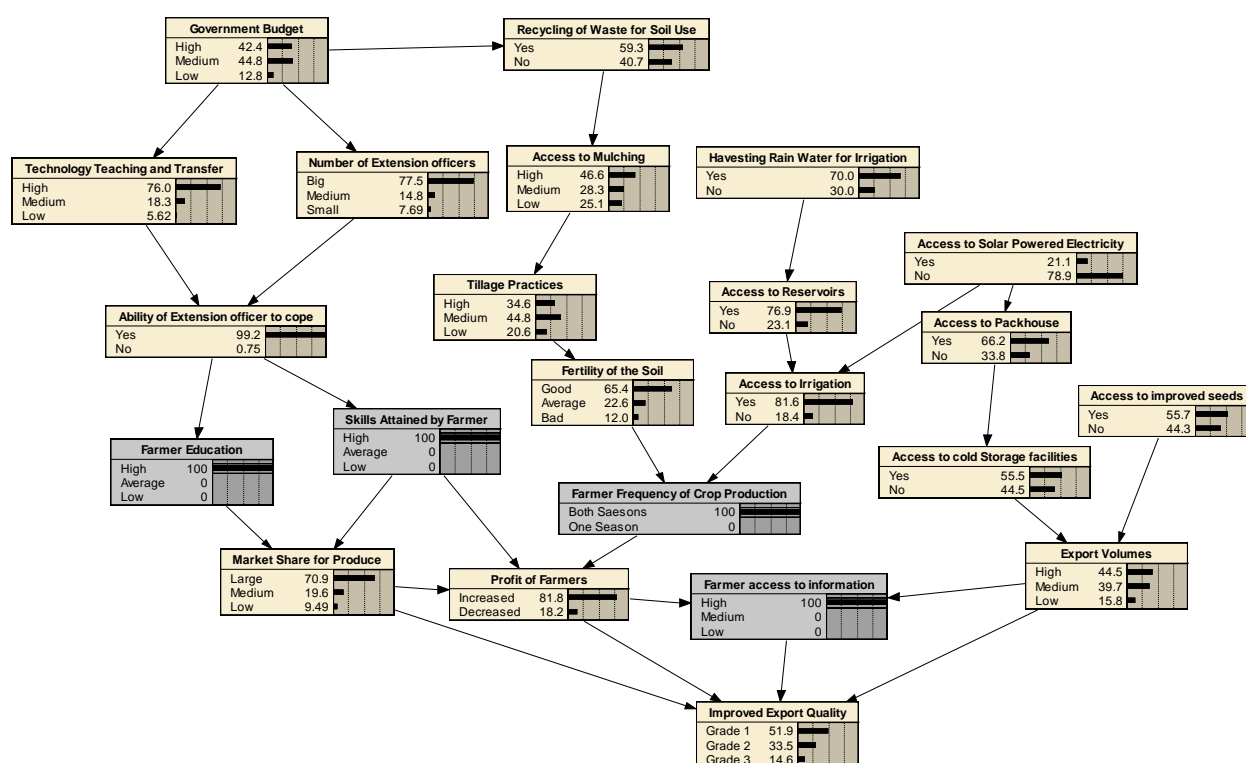
Figure 2.9: BBN simulated model of improving quality

Figure 2.9 starts with the node representing the management objective: 'improved export quality'. Feedback arises from the combined interaction between farmers' education, skills and access to information, and the frequency of cropping is greater than the sum of their individual effects. As the BBN is a network, the effect of changing these variables is transmitted throughout the network in accordance with the relationships expressed by the conditional probability tables (CPTs). CPTs are used to express how the relationships between the nodes operate. If the 'improved export quality' is within acceptable levels, a significant increase would be expected in market share, profit, access to irrigation and export

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volumes, while having a positive effect on others within the network. With this information, the intervention can be adapted to encourage positive feedback.

The expected outcomes are presented in Table 2.2. This simulation provides additional opportunities to test possible strategies before any time or money is invested in implementation.

Table 2.2: Outcome of possible strategies of Figure 2.9

Factors	Before intervention (%)	After intervention (%)
Export volumes	33	44.5
Export of grade one quality	40.4	51.9
Market share	58.4	70.9
Agricultural productivity	61.8	81.8
Ability of extension officer to cope	67.3	99.2
Technology teaching and transfer	58.5	76
Number of extension officers	66	77.5

The BBN model will be further developed and refined as the study progresses. The identified strategies, in addition to the operational plan to interpret the agricultural system, will be applied at a later stage of this study.

2.5 Conclusion

This research presents four CLDs for generic integrated mental models of the agricultural management system in Africa. It is believed that the diagrams are more complete than any found in the existing literature. These models have provided insights into potential system behaviours and identified leverage points for the systemic interventions required to sustain and improve the current quality levels of agricultural exports from African countries. This approach will help governments, managers, scientists, decision makers and policymakers to anticipate the long-term consequences of their decisions and actions, and help to avoid any significant unintended consequences of policies and strategies resulting from a 'silo mentality' and 'organisational myopia'.

These models will be refined further and validated through continued focus group discussions with stakeholders in the agricultural industry in Ghana. As demonstrated in the above CLDs and BBN model, agriculture will continue to be the engine that develops and empowers the emerging and existing commercial agribusiness sectors and entrepreneurs across Africa. This systems thinking approach will also provide more clarity in dealing with complex sustainability challenges and gradually replace the traditional linear way of dealing with challenges.

2.6 Acknowledgements

Chapter 3: Paper Two: Systemic Structure, Conduct and Performance of Agriculture

■ Research Paper

A Systems thinking Approach to the Structure, Conduct and Performance of the Agricultural Sector in Ghana

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The continuous growth in population and consumption, the intensity of competition for land, water, and energy, and the overexploitation of the ecosystem, have all affected Africa's ability to sustain its food security and natural resources. In recent years, many promising agricultural development initiatives were unable to provide sustainable solutions to agricultural challenges in most parts of Africa, including Ghana, as a result of policy failures. The agricultural sector is a complex system and requires a holistic approach to deal with the root causes of challenges. This research therefore uses systems thinking tools, including Causal Loop Diagrams (CLDs) and Bayesian Belief Network (BBN) modelling, to develop new structural systems models whereby stakeholders can determine the components and interactions between the Structure, Conduct and Performance (SCP) of the agricultural sector in Ghana, using the first five steps of the Evolutionary Learning Laboratory (ELLab). The results illustrate how the SCP elements interact together to influence the survival and growth of the agricultural sector. The study identifies that stakeholders adopt several strategies to survive and compete, which lead to overexploitation of the ecosystem. The results from the BBN models indicate that the implementation of systemically determined interventions, policies and strategies could significantly improve the probability of business survival and growth from 58.8% to 73%. Also the chances of improving the SCP could be increased from 39%, 28.3% and 36.4% to 80.1%, 55.9% and 62.4%, respectively and these may vary based on the conditional probability tables (CPTs). This paper contributes to the systemic approach to SCP, in that improvements to production and allocative efficiency may usher in a greater potential for improving food security, supporting the ecosystem and further strengthening agricultural sustainability.

Keywords: allocative efficiency; market analysis; policy decision; market information; business survival.

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Principal Author

Name of Principal Author (Candidate)	Kwamina Ewur Banson
Contribution to the Paper	The conception and design of the manuscript, establishing methodology, conducting workshops in the study area for data collection and models validation in Ghana. Compiling, analysing and interpreting data, working on the development of the first draft manuscript and the writing and submission of the final version.
Overall percentage (%)	85%
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature	Date	22/06/2016

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

    i.   the candidate's stated contribution to the publication is accurate (as detailed above);

    ii.   permission is granted for the candidate to include the publication in the thesis; and

    iii.   the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Nam C. Nguyen (Principal Supervisor)
Contribution to the Paper	Supervising and assisting with the establishment of methodology, planning of the survey, discussions, supervising development of first draft, editing and co-authoring the manuscript.
Signature	Date	27/06/2016

Name of Co-Author	Ockie J. H. Bosch (Co-Supervisor)
Contribution to the Paper	Supervising and assisting with the establishing of methodology, editing and co-authoring the manuscript.
Signature	Date	28/06/2016

Please cut and paste additional co-author panels here as required.

3.1 Introduction

Agriculture remains a mainstay of Ghana's economy, accounting for 40% of GDP and about 70% of formal employment (Abatania, Hailu & Mugera 2012; Chisenga, Entsua-Mensah & Sam 2007; Khor & Hormeku 2006; Banson, Bosch & Nguyen 2015). The importance of agriculture is even greater than these figures suggest, as ecological and cultural boundaries also depend on agriculture, which is essential to sustainability. Other sectors of the economy are also linked to agriculture, including processing and the transport and trade of agricultural products and materials (Khor & Hormeku 2006). Thus, the agriculture sector (and especially the subsectors that produce food) is critical in the provision of incomes and livelihoods, and developments within this sector are important in terms of attaining the Millennium Development Goals of eliminating poverty (Pisupati & Warner 2003). The government is committed to improving crop production, and knowledge about the technical efficiency of crop farms is essential in guiding policy decisions (Abatania, Hailu & Mugera 2012). In recent years, agricultural growth in Ghana has been positive overall, but much of this growth has resulted from area expansion rather than increased yields (International Food Policy Research Institute 2007). The agriculture sector, which has undergone significant economic, social and political changes since the beginning of the democratisation process in 1957, is increasingly facing challenges such as vulnerability to food insecurity (Banson, Nguyen & Bosch 2015b). The combination of liberalisation and reforms of the 1970s, which resulted from the economic transformation, also exposed the agricultural sector to the adverse effects of globalisation, such as increased and unfair competition, which hinders the growth of infant industries (Chitiga, Kandiero & Ngwenya 2008; Khor & Hormeku 2006). Large importers in Europe play a decisive role in structuring the production and marketing of primary products exported from Ghana. The requirements that importers specify for innovation—for instance, new product development, delivery, food safety and quality systems—determine what types of producers and exporters are able to compete in the export market and maintain access to the agribusiness chain (Humphrey 2005). These place smallholder producers in a marginalised position in the export sector. Smallholders constitute 90% to 95% of the farming population and produce 80% of the agricultural annual output (Abatania, Hailu & Mugera 2012).

These effects, along with the marginalisation of farmers—especially smallholders—is further worsened by farmers' inability to handle the costs and administrative burdens of compliance with global standards. Traditional approaches to agricultural innovation and management can have substantial economic, social, environmental and political effects on the SCP of the agricultural industry, not only in Africa, but around the world (Banson et al. 2015).

Traditional agriculture management is performed by identifying levels of resolution to parts of an element within a holistic system and has been judged successful based on determinations by crop yield and devoid of the issues of sustainability, inter-relationship and ecosystem wellbeing (Barrett 1992). Agriculture is facing many challenges, which can be characterised by low productivity, poor quality, chemical residues in products, poor service quality, and high production and transaction costs, as a result of traditional approaches to agricultural sustainability (Hilborn, Walters & Ludwig 1995). The consequences of traditional approaches to agricultural management have increased awareness of the need for the amelioration of the rapidly deteriorating state of the ecosystem and of the enhancement of the sustainability of resources (Banson et al. 2015; Lubchenco et al. 1991).

These problems will be exacerbated by projected climate changes and a projected increase in extreme events (Intergovernmental Panel on Climate Change 2001; Rosenzweig et al. 2001). The production and livelihoods of those working in agriculture will be affected, as high temperatures can determine whether they survive. Failure to address these problems will make it impossible to ensure food security, sustainability, equitable development and eradication of poverty in Africa.

Over the past 6 decades, many promising agricultural research papers, policies and development initiatives have been unable to provide sustainable solutions to any national and regional agricultural challenges in most parts of Africa (including Ghana) as a result of policy failures (Banson et al. 2015).

These consequences can be minimised through a shift from the reductionist approach towards a holistic management approach that utilises the SCP of the agricultural industry, which can reveal any significant unintended consequences before resources are invested in implementation, in order to increase agricultural competitiveness. The traditional SCP approach was first used by Bain (1951) to account for inter-industry differences in profitability. The basic premise of the SPC is that the structure (i.e., the number of farmers and traders, number of markets, quality and quantity of infrastructure support) affects conduct (production and marketing practices, including pricing), which in turn affects performance (prices, quantities and profits) (Hanekom, Willemse & Strydom 2010; Milagrosa 2007).

In addition to traditional research approaches to agricultural innovation under poor policies, stakeholders have adopted many survival strategies that have contributed to soil exploitation and the destruction of natural ecosystems for their economic survival (United Nations 1987). As cited in Klerkx, van Mierlo and Leeuwis (2012), a wide range of approaches to agricultural innovation have emerged over the past 40 years. These include induced innovation (Ruttan & Hayami 1984), transfer of technology (Jarrett 1985), participatory

research and technology development (Farrington & Martin 1988), problem solving algorithm for resource management (Barrett & Bohlen 1991), training and visit system (Hulme 1992), farmer first (Chambers & Thrupp 1994), and agricultural knowledge and information systems (Rivera & Qamar 2005; World Bank 2000). All of these approaches have attempted to overcome the challenges of a complex world without seeing beyond the details to the context of the relationships in which the problems are embedded in order to display the behaviour of cause and effect from a systems viewpoint (Banson et al. 2015; Mai & Smith 2015). As a result, billions of dollars have been wasted in unsuccessful interventions (Banson et al. 2015). These have led to shifts in neoclassical theoretical perspectives on agriculture (see Figure 3.1) since the 1960s. As indicated in Figure 3.1, earlier theoretical perspectives on agricultural innovation can be found in the systemic approach, which goes beyond traditional approaches to alert managers of significant future unintended consequences to ensure cost-effective plans of action in integrated strategic management (Banson et al. 2015).
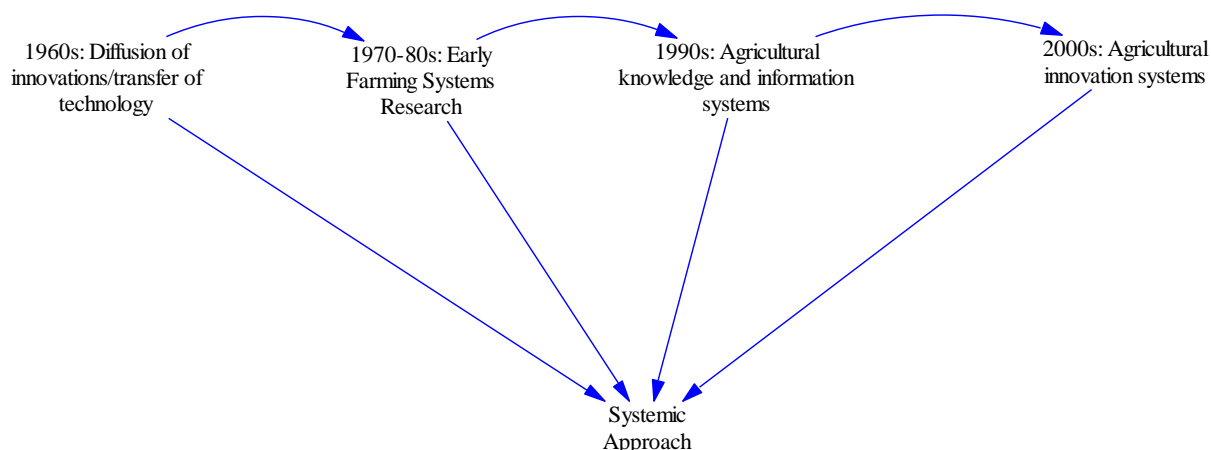
Figure 3.1: Shifts in theoretical perspectives of agricultural innovation

The application of systems thinking to the SPC model is designed to identify a set of hypotheses about how relationships within the structure of a system influence its behaviour given a set of interactions among driving forces (Gali, Tate & O'Sullivan 2000). This also satisfies the demand for new approaches to traditional business models (Barile et al. 2012; Gali, Tate & O'Sullivan 2000).

Systemic thinking highlights and addresses challenges using integrated approaches where the uncertainty of the SCP of a particular system is mapped to determine how the components relate to each other and to identify a leverage point. Systems thinking principles lend themselves to effective decision making and business planning. Changes that are expected to occur within the complex agricultural system cannot be predicted within the boundaries of the neoclassical approach and historical data reported by traditional sources. For long-term planning and policymaking, it is necessary to develop an understanding of unintended

consequences, and to develop scenarios for the likely structure of agriculture and its food and ecosystem systems.

It is clear from the earlier discussion that the challenges in Africa are complex. To help address these, there is a need to equip policymakers, researchers and all relevant stakeholders with a new way of 'thinking' that moves beyond the traditional, linear approach to solving problems towards a holistic systems approach that focuses on the root causes and interconnectedness between various components of the agricultural sector.

This paper forms part of a PhD thesis addressing the key issue of 'the pressing constraints and challenges facing stakeholders and the performance of the agricultural sector in Ghana'. Therefore, the main goal of this research is to develop a new structural approach in partnership with stakeholders to help improve the SCP of food security in Ghana using the ELLab. This new research effort addresses the inter-relationships and patterns underlying the SCP within the agricultural industry in natural and human-dominated ecosystems in order to recommend restoration and management strategies that will enhance the sustainability of the whole system. This paper focuses on the application of systems thinking tools such as CLDs and the BBN model, which are appropriate for planning and decision support.

3.2 Research Approach

3.2.1 Systems Theory

Systems theory provides a framework for taming complexity, in other words, providing systems concepts and tools to unravel the complexity of any system under consideration. Many systems theories emphasise different aspects, including market information theory (derived from the pioneering work of Shannon 1996), cybernetics (Wiener 1954) and second-order cybernetics (Von Foerster 2003). Systems theory has evolved to another level, called chaos theory, which refers to the dynamics of a system that apparently have no or little underlying order (Charlton & Andras 2003; Larsen-Freeman 1997; Levy 1994). In these systems, small changes can cause complex changes in a holistic system. Chaos theory has led to new perspectives and tools to study complex systems such as agriculture, biology, humans, groups, weather, population growth and the solar system.

This research approach builds on the ELLab of Bosch et al. (2013) and aims to introduce systems theory for researchers, research managers, policymakers and other decision makers in order to develop a shared understanding of complex issues and create innovative and sustainable solutions using systemic approaches. The stakeholder theory of organisational management and business ethics, which was originally detailed by Freeman (2010) and addresses morals and values in managing an organisation, is the basis of the ELLab. In the

ELLab, the stakeholder approach identifies and models the stakeholder groups within an industry and both describes and recommends systemic interventions through which management can give due regard to the interests of those groups (Donaldson & Preston 1995). According to Grimm et al. (2000), stakeholders must be integrated into models for a complete understanding of extant systems, which leads to greater success in finding realistic solutions to challenges. The research processes include generic skills in problem solving, team participation and team learning. The ELLab consists of a seven-step process for gathering the mental models of stakeholders for collaborative problem solving. This ensures the adoption and implementation of sustainable outcomes, as the mental models and solutions are derived from or owned by the stakeholders.

This research approach is in agreement with the pragmatic view that absolute knowledge is not possible; thus, the ELLab process offers reflections at regular intervals on the outcomes of the interventions, which are designed to reinforce that no systems model can ever be completely 'correct' in a complex and uncertain world.

3.2.1.1 Evolutionary Learning Laboratory

The SCP of Ghana's agricultural sector were analysed using the ELLab approach. The study was conducted in the Greater Accra Region of Ghana, where agriculture is the main economic activity in peri-urban regions. Stakeholders (farmers, extension agents, research scientists and traders, including wholesalers, retailers and input dealers) in this region were selected randomly from a database obtained from the MOFA for the study, as more than 80% of the population depends on agriculture and related activities (Banson et al. 2014; Banson et al. 2015). The city also hosts most of the offices of the market-oriented agriculturalists. Questionnaires were addressed during a series of workshops organised in Ghana, which engaged 75 agricultural stakeholders to identify key drivers affecting the performance of the agricultural sector in Ghana. The BBN and other models were validated by organising another series of workshops in 2014 for further stakeholder group consultations (the same stakeholders involved in the first workshops in 2013) to confirm and validate all of the models.

Figure 3.2 illustrates the ELLab, where the initial step starts at the 'fourth level of thinking' and involves a series of workshops with stakeholders to gather their mental models through engagement and exploratory questions.
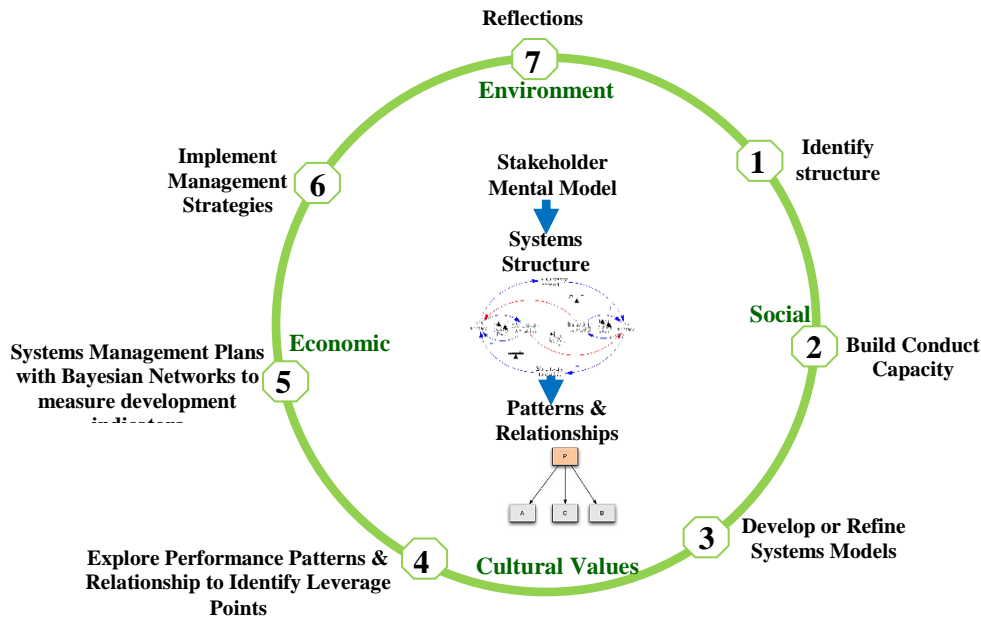
Figure 3.2: Elements of the paradigm: a systemic approach (adapted from Bosch et al. 2013)

A combination of the literature review and data obtained in the workshops, along with the use of the Four Levels thinking model embedded in the ELLab, gave an overview of the current state of the SCP model. This was followed by step two, which is the 'third level of thinking'. This is developed through follow-up capacity-building sessions, during which the participants and researchers involved in the workshops learn to integrate the various mental models into a systems structure using the Vensim software program (Ventana Systems UK 2002). It is important to note that capacity-building is an integral part of all steps of the ELLab process to examine farmers' and traders' behaviour, both among themselves and among each other's competitors. Firms such as input suppliers, research institutions and policymakers choose their own strategic behaviour, investment in research, development, advertising levels and collusions. Upon completion, the participants moved to step three—the 'second level of thinking'—by interpreting and exploring the model for patterns, interconnected components and analysed feedback, reinforcing and balancing existing loops. This step was aimed at assisting stakeholders to develop an understanding of their interdependency, role and responsibility in the entire system. These processes led to step four, which gave stakeholders a better understanding of each other's mental models and the development of a shared understanding of firms' performance in efficiency terms. The interpretation led to the identification of leverage points for systemic intervention. Leverage points are places within the complex agricultural system where a small intervention at a specific point can generate a significant effect. In step five, the identified leverage point was used to develop a refined systems model for the identification of systemic interventions. For this, BBN modelling was used to identify the systemic interventions and determine the requirements for the

implementation of the systemic management strategies and/or systemically based policies (Bosch et al. 2013). The structure of the BBN model and its data for the CPTs were developed and obtained from the literature review and focus group discussions with experts (Banson et al. 2015). The BBN is used as a simulation model to test the possible outcomes of different systemic interventions by observing what will happen to the system as a whole when a particular strategy or combination of strategies is implemented—that is, before any time or money is invested in implementation.

This research focussed on the first five steps of the ELLab process. Steps 6 and 7 are the actual implementation of the management strategies and reflections on the outcomes at regular intervals.

3.2.2 Justification for the Methods and Techniques Used

This research focuses on the application of the ELLab and BBN as knowledge integration tools in sustainable agricultural management and decision making. The ELLab is designed to equip policymakers, researchers and all relevant stakeholders with a new way of 'thinking' beyond the traditional 'linear' approach of solving problems to a holistic systems approach that focuses on the root causes and interconnectedness between various components of the agricultural system. BBN are used after the identification of the leverage points from the CLD designed as a result of the ELLab process. The BBN decision-making approach involves stakeholders participating in solving management problems using systems thinking to identify and relate factors that may affect management objectives (Smith, Felderhof & Bosch 2007). The process involves setting management objectives, abstract modelling to explore the effect of decisions on these objectives, identifying preferred management interventions and monitoring to track the success of implemented management interventions.

The purpose of these approaches is decision support, policy assessment and the prioritisation of management interventions. The BBNs are used for knowledge integration and as a decision support tool because their graphical nature makes them relatively easy for stakeholders and non-modellers to understand (Smith, Felderhof & Bosch 2007). BBNs also use probabilities to relate system factors, thereby giving users the ability to accommodate uncertainty in their decision making. These probabilities can come from several different sources, including available dataset, expert opinions and other models (Banson et al. 2015). BBNs can also be used for scenario and sensitivity analysis quite quickly and easily, thereby allowing stakeholders to identify management intervention points and potential consequences of management and policy decisions before implementation.

3.3 Results and Discussions

3.3.1 Pressing Constraints and Challenges Affecting Agricultural Performance

Forty-six out of the 75 respondents were farmers. Agricultural produce distribution in Ghana can be described as having two types of distribution channels: long distance and peri-urban agriculture. Most farmers (95.6%) involved in the study are peri-urban farmers who primarily produce perishable items. These goods tend to be sold directly to consumers through the domestic market by farmers' relatives or traders, and they must generally reach the consumer within 24 hours due to a lack of refrigeration storage (Ortiz, Campbell & Hyman 2010). These traders consist of itinerant middlemen, retailers, wholesalers and individual households or fellow farmers. A minority (4.4%) group of farmers who live in the outskirts of peri-urban areas travel long distances to enter the market through Community Supported Agriculture (CSA) networks, farmers' associations or middlemen before reaching the consumer. The study found that at the village level, a farmer's first option is selling his or her farm produce at the local market or at the closest main road to the village. The second option is through 'itinerant wholesalers', who mostly travel from village to village to buy farmers' produce at the farm gate. The third option is through farmers' associations, which then organise themselves and jointly hire a truck to transport their farm produce to markets in the cities. Out-grower schemes are common in Ghana; this is when agricultural production is carried out according to an agreement between larger companies and small farmers. Developing out-grower nucleus schemes is a sure way to increase the productivity of small-scale farmers, reduce competition and increase market share by using economies of scale. Typically, farmers agree to provide established quantities of a specific agricultural product and meet the quality standards and delivery schedule set by the larger companies. In turn, the larger companies commit to purchase the product, often at a predetermined price (Banson, Nguyen & Bosch 2014). In some cases, larger companies also commit to support production through, for example, training, supplying farm inputs, land preparation, providing technical advice and arranging the transport of produce to the larger company's premises. With this scheme, small farmers often have improved access to assured markets and prices (lower risks) with relatively higher returns (Banson, Nguyen & Bosch 2014).

However, most highways off main towns and cities in Ghana are in poor condition. Farmers who live far from good roads are marginalised, not only because they have difficulty in reaching markets, but because traders avoid farms in areas off good roads because transport costs are too high (Bryceson 2002; Eskola 2005). Despite the long distances involved, farmers play an important role as food growers and rural stewards. The low prices of produce, combined with poor terms of trade and currency devaluation, have led many farmers from

market-oriented production to subsistence farming (Ferris et al. 2014). One of the principle and most influential stakeholders in this network is the group of itinerant wholesalers and exporters who are the primary financiers of farming costs and thus share any risk of crop failure. They often earn high financial returns on their agricultural investments, which generates criticism from stakeholders who see this as unfair practice within the food distribution process (Ortiz, Campbell & Hyman 2010).

The majority of farmers (45 of the respondents) sell produce to traders or middlemen. Traders serve as a source of quantity and price information, and they act as guarantors between farmers and consumers in the supply chain. A number of studies in produce supply chains have documented that smallholder farmers incur high transaction costs, which are linked to the search for produce buyers, market information, negotiation and other costs associated with marketing their farm produce (Hananu, Abdul-Hanan & Zakaria 2015; Poulton, Kydd & Dorward 2006). Figure 3.3 illustrates the major challenges encountered by both small- (65.2%) and large- (34.8%) scale farmers in this study.
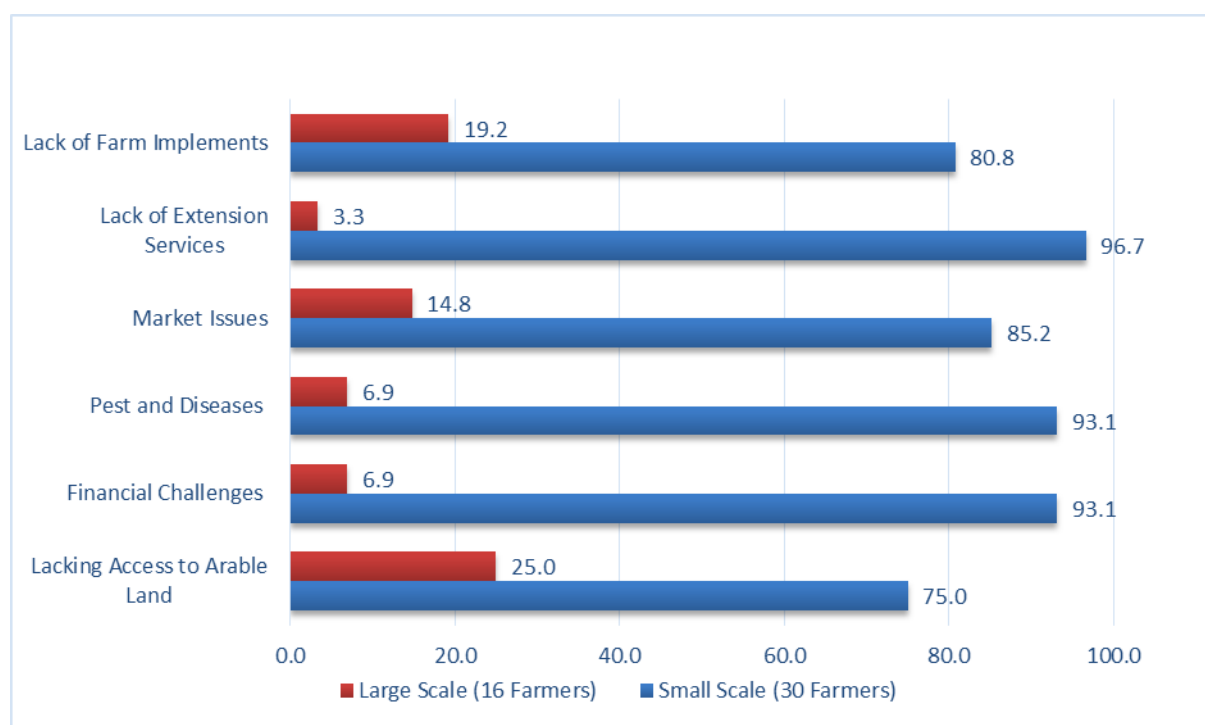
Figure 3.3: Major challenges encountered by large- and small-scale farmers (%) (Source: data compiled from fieldworks conducted by the authors in Ghana in 2013-2014)

Small-scale farmers cultivate land sized between one and 12 acres (Banson 2014), with an average of 2.3 acres across the respondents. Large-scale farm size is more than 12.5 acres, with an average of 14.2 acres across the respondents. Financial challenges were major impediments to both small- and large-scale farmers' access to new arable land and farm implements. However, these challenges affect small-scale farmers more intensely than their large-scale counterparts. Large-scale farming has economies of scale in the production of

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quality produce at a relatively low cost due to their already-established markets, as shown in Figure 3.3. Agricultural extension is part of the MOFA, with field extension officers providing services to farmers through training activities to improve farming techniques, increase production efficiency and income, improve their standard of living and lift the social and educational standards of rural life (Banson, Nguyen & Bosch 2015a). Smallholder farming operations are typified by *ad hoc*, uncoordinated individual plantings or raising livestock where no authorisation is required from the relevant authorities; thus, there is no record of the exact number of farmers cultivating in Ghana (Banson, Nguyen & Bosch 2014). This system has made it difficult to determine the number of extension officers that need to be deployed in a particular region to help these farmers. Further, a lack of extension services means that there is an insufficient number of extension agents to deploy to serve a particular farming community.

3.3.2 Prioritisation of Systemic Intervention(s) by Stakeholders

Table 3.1 illustrates the key variables of focus group discussions among stakeholders deliberating on the constraints and challenges affecting their agribusinesses, the effect of these constraints, and suggested potential strategies or solutions needed to overcome these challenges. These variables are organised into four main categories: farmers, input dealers, government: MOFA and research institutions (see Table 3.1). Using a CLD modelling approach leads to the formation of a systemic SCP model for the sector:

Table 3.1: Intervention by stakeholders to agricultural constraints

Questions	Respondents			
	Farmers	**Input dealers**	**Government (MOFA)**	**Research institutions**
a. Identify pressing constraints and challenges affecting agricultural activities in your sector.	-Finance -Little to no access to arable lands -Pests and diseases -Difficult access to extension/veterinary services -Unreliable rainfall patterns -Poor breeds and seeds -Lack of markets -Government budgets do not reach farmers -Poor policy	-Difficulty in getting EPA registration for new products -Stringent protocols of CRIG for fertilisers -Lack of local markets for direct sales to farmers -Competing with cheap products looted into the country from neighbouring border countries -Lack of farmers' trust in product(s) due to their experience with fake ones in the markets	-Lack of/ insufficient machinery (tractors, logistics, finance), -Irregular finance to travel and visit farms -Farmers' inability to form lasting associations as a point of knowledge transfer. -Lack of research extension farmer linkages -Farmers' inability to adopt technology -Distant farming lands	-Lack of/insufficient funding to start research -Inadequate and obsolete laboratory equipment -Dependency on traditional tools as a result of a lack of sponsors for further training -Inadequate technical knowhow -Researchers do not liaise/correspond with primary industries
b. What are the effects of	-Loan default -No education for	-Difficulties in introducing new and	-Inability to transfer innovations to	-Delays in finding solutions to

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these challenges on key variables?	children -Low productivity -Failure of farm -High risk of investment -Failure to assume household responsibilities	effective brands, -Sales reduction -Inability to reach farmers with quality products	farmers -Lack of enthusiasm -Lack of response from immediate supervisors -Extension officers' persistence for the right actions can lead to victimisation and job losses	pressing challenges -Ideas cannot be materialised -Publication difficult -Low productivity of research output
c. What new strategies are needed to overcome these challenges?	-Enactment of laws to reserve arable lands -Dam construction for irrigation access -Construction of road access from farms -Registration and provision of ID for farmers' recognition -Provision of electronic tracking systems to record extension officers' visits -Construction of local markets in each community -Creating avenues to announce market information and research breaks for farmers	-Enforcing border controls and creating avenues to report fake products on the markets. -Frequent inspection of existing brands by EPA and Quality Control -Periodic testing of the quantities of A.I. in the chemicals and markets -Training and linking with research institutions to address current challenges -Developing local markets and road networks to farming communities	-Creation of green belts for farming purposes by local governments -Commercialisation of extension services -Extension officers' access to agricultural publications and electronic bulletins -Government to provide incentives for long-lived farmer associations -Reducing workload per extension officer by decreasing the extension officer to farmer ratio -Sustainable sources of logistics	-Educate agricultural sector and government on the importance of research to development -Making research funding a priority -Investment in new equipment and training programs for researchers -Making it the law for all primary industries to have a link with local research institution -Making it the law for all research institutions to showcase quarterly achievements to extension officers, primary industries and farmers
d. What factors can influence these new strategies from being implemented?	-Availability of arable land in the peri-urban regions -Current government policies -Lack of funding from the government -Land ownership and family land disputes -Low profit and productivity	-Government politics and bribery of law enforcement officers -Lack of government financial support	-Lack of government funding -High interest rates and depreciation of local currencies	-Lack of vision by the ruling government -Lack of specialised research scientists
e. How can these factors be managed?	-Registration of arable lands to true owners -Government to buy arable lands outright from owners for farming purposes	-Punishing corruption and bribery severely -Reward crime stoppers significantly	-Generating local sources of funding through tax	-Taxing primary industries and consumers for funds for research and development

3.3.3 Systemic Structure, Conduct, Performance Model

The CLD in Figure 3.4 illustrates how the market structure, firm/industry conduct and performance elements interact to affect the competitiveness and performance of the agriculture industry holistically, considering the potential benefits to consumers and society as a whole. The CLD model was developed during the workshops, where respondents learnt to integrate the various mental models into a systems structure. The CLD consists of variables connected by causal arrows with polarities such as same 'S' and opposite 'O' signs to describe the causal linkages (Banson, Nguyen & Bosch 2015a). If the causal arrow from one element 'A' to another element 'B' is the same (i.e., 'S'), then either 'A' adds to 'B' or a change in 'A' produces a change in 'B' in the same direction. However, if the causal arrow from one element 'A' to another element 'B' is opposite (i.e., 'O'), then either 'A' subtracts from 'B' or a change in 'A' produces a change in 'B' in the opposite direction. Feedback loops describe the circles of cause and effect that take on a life of their own. Feedback is often necessary within management systems to understand what is causing the patterns of behaviour. That is, the causes of an observed pattern of behaviour are often found within the feedback structures for a management system. The arrow links in Figure 3.4 form feedback loops. This indicates that a given change kicks off a set of changes that cascade through other factors to either amplify ('reinforce' [R]) or push back against ('damp', 'balance' [B]) the original change. The delay symbol '║' is the time lag before the actual state is perceived. For example, when there is a change in policy decisions, it usually takes a while before its effect on performance is perceived.

3.3.3.1 Structure

A structure is a set of variables that are relatively stable over time and affect the behaviour of farmers and/or buyers (Banson 2014; Policonomics 2012). The median number of farming years among farmers was 24.5 years, and 75% had at least a primary school education. The study identified that access to arable land and start-up costs are substantial barriers for new farmers entering the agriculture industry. These are the main issues faced by both new and experienced farmers, with a shortage of direct farm ownership experience. Access to arable land also leads to natural resource depletion and effects on the ecosystem. Stakeholders attested that the requirement to have at least 25% as a down-payment to purchase arable land proved to be the most challenging barrier for new entrants and farm expansion. These rules were intended to affect the average farm size available for cultivation. Figure 3.4 illustrates that as the barriers to entry increase, access to arable land per farmer reduces, which in turn causes the average farm size to fall. A stronger farmer's association represents a lower or

weaker barrier for a new farmer to enter because the larger the association, the better access they have to bank credit and tractor services. Most tractor operators are not utilised to their full capacity after long-distance travel as the result of a small number of members involved in an association; thus, they do not provide services to long-distance farmers. A strong farmer association of small farmers for the collective use of a tractor justifies tractor access and the costs associated with long-distance travel. Access to tractor services liberate the severe limitations on the amount of land that can be cultivated per family. As a result, more time is spent on the farm with boundless efficiency, thereby increasing crop yields and productivity.
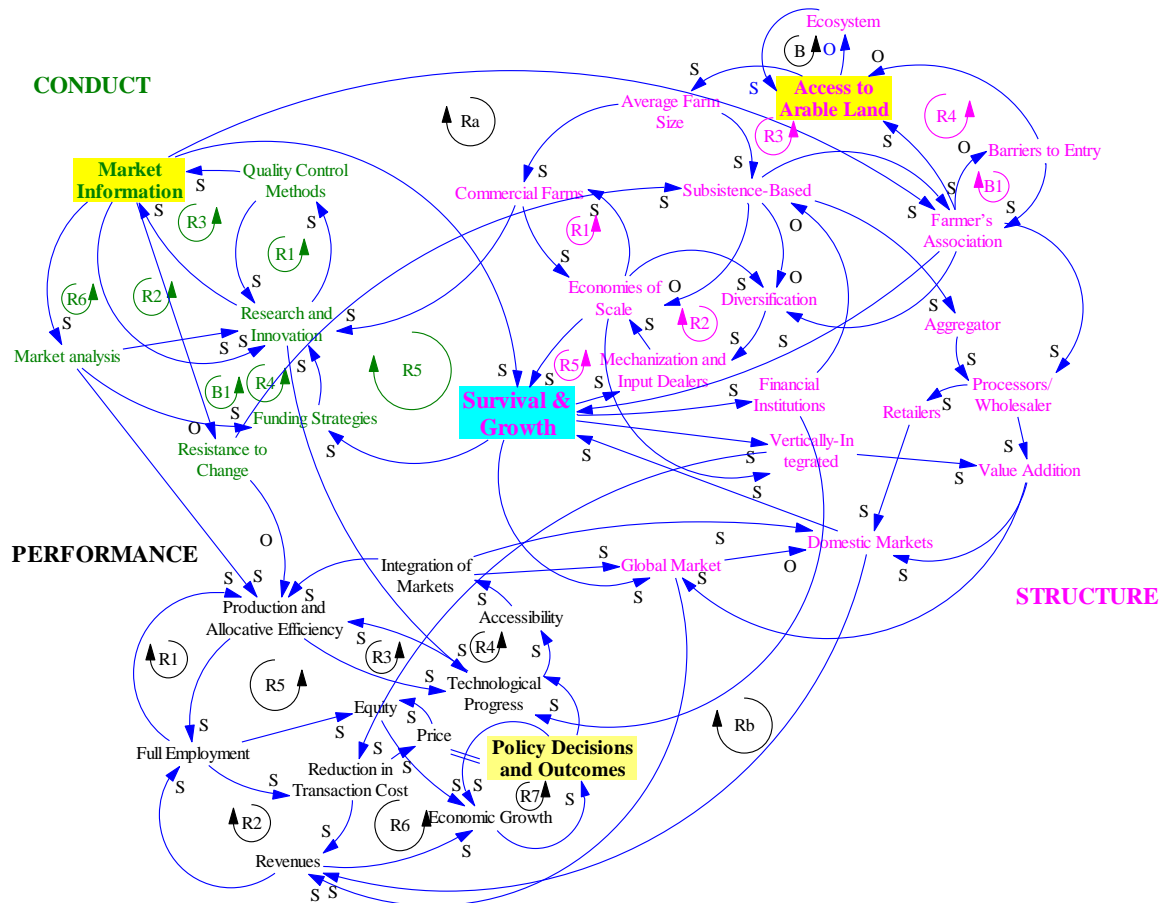
Figure 3.4: Systemic SCP model

Access to smaller acreages or fewer resources affects the scale of production, food security, economy and job availability. As subsistence-based production increases, the chance of forming a farmer's association also increases, which gives this group of farmers access to market information through extension agents and/or buyers. Access to market information changes the conduct of subsistence-based farmers to market-oriented production. This tends to give them access to revenue, which reduces their financial barriers to entry or expansion. This reinforcing loop makes sense, but it will only come into play once resource constraints are a serious issue. Conversely, access to arable land and start-up costs are not resource constraints; the average farm size is large, which leads to commercial agricultural activities

ranging from intensive crop production to mixed farming. This gives large commercial farmers economies of scale, which are typically vertically integrated, giving their agribusiness a competitive advantage and reductions in transactions (performance) on the global market, as shown in Figure 3.4.

3.3.3.2 Conduct

Conduct is the way in which buyers and farmers behave, both among themselves and with each other (Banson 2014; Policonomics 2012). Figure 3.4 illustrates that access to market information directly influences market analysis, which is intended to determine the types of investment needed for research and innovation. This creates reinforcing loops, as shown in Figure 3.4. As commercial farmers or companies invest in research and innovation, these elements increase their market information and reinforce their quality control methods. Investment in research and innovation increases technological progress, which reinforces production and allocative efficiencies (R3, under performance).

3.3.3.3 Performance

This is the result of the industry in efficiency terms and at different profitability levels (Banson 2014; Policonomics 2012). In Figure 3.4, the policy decisions and outcomes affect technological progress (Nallari et al. 2011). As technological progress increases, production and allocative efficiency also increase. When this happens, there is a full employment of resources, which leads to a reduction in transaction costs. This in turn leads to a reduction in price, and price reductions lead to more money in consumers' pockets. This in turn improves the profitability margin of farmers and companies. As such, an increase in consumer spending will further catalyse national economic growth (see Figure 3.4).

3.3.4 Adaptive Conduct Mechanisms to Survive within a Failing System

3.3.4.1 Farmers

Farmers adapt many survival strategies to be competitive. Growing populations with a shortage of arable land have led most farmers to seek new land in forest space to grow more food and seek off-farm income (VanWey & Vithayathil 2013). Long-distance farmers (5%) follow a traditional path of purchasing or renting more land to increase their acreage in order to increase their production volume. Although this results in increased income, it also results in the depletion of natural forests and ecosystems. Forests are crucial for maintaining and improving the productivity of agricultural land. Peri-urban farmers, who represent 95% of the respondents, intensify operations to increase productivity through the use of chemicals such as fertilisers and pesticides to earn more income from the same piece of land. The run-off of these chemicals damages water resources, which then spread the chemicals and threaten the

health of humans and animals. An example of farmers generating revenue streams to supplement farming activities is when some farmers involved in this study went to the extent of mixing Furadan with the soil as bait for grass cutters (*Thryonomys swinderianus*), which then eat the mix, become bloated and die on the spot. They are then processed for sale to consumers. Other farmers use poisonous chemicals for fishing, polluting water bodies and killing other living organisms in the water, thereby destroying the natural balance of the ecosystem for short-term gain.

A 1983 study estimated that approximately 10,000 people die each year in developing countries from pesticide poisoning, and about 400,000 suffer acutely because pesticides travel through the food chain (United Nations 1987). These numbers have more than doubled with increased chemical usage. Some farmers also engage in felling and tapping wild palms for palm wine. Farmers use a number of strategies to survive and strengthen their business in a failing system to ensure they are not as vulnerable to system fluctuations. In the long run, the ecosystem and its resources become depleted and worsen the plight of these farmers, as most of their practices are not ecologically sustainable in their own area. Many youths in farming communities see agriculture as an uncompetitive and unprofitable venture, and hence migrate to greener pastures. This results in a lack of succession planning of parental businesses, thereby posing a significant threat to the long-term existence of family farming.

3.3.4.2 Traders

Traders do not have appropriate storage facilities and therefore prefer to deal with peri-urban farmers, where they harvest directly from the farmers' fields when there is market demand and pay after selling, which minimises their risk in the value chain. Traders—especially wholesalers and exporters—may also fail to comply with an agreement to buy a specified farmer's produce when they detect poor markets, thereby forcing farmers to sell cheaply to domestic markets or processing companies. Traders take away the 'lion's share' of the benefit accrued from the sale of farmers' produce by taking advantage of small farmers' lack of awareness of market prices and weak bargaining power, which arise from low literacy levels and low social status (Pokhrel & Thapa 2007). They also engage their young children in marketing to maximise their market share, thereby depriving these children of an education. Traders sometimes engage in illegal logging and wildlife trading; poaching of endangered species by farmers or community members can be used to earn additional income to support their family. These elements, combined with seasonal shortfalls of cash, a lack of storage facilities in villages and farmers' limited awareness of market prices, have given traders a further advantage over farmers in terms of their bargaining power.

3.3.4.3 Firms

Lax government control has resulted in private firms regulating virtually the entire food cycle—inputs and outputs, domestic sales, exports, public procurement, storage and distribution, price controls and subsidies—and imposing various land use regulations in terms of acreage and crop variety. The manufacturing sectors claim that they have lost working capital as a result of the continued rise in the price of imported inputs due to the depreciation of the local currency. Thus, firms indulge in management's game plan for strengthening its organisational position (Gumbe & Kaseke 2011). The survey findings revealed that firms apply different strategies, such as quantity reductions, which demand the same standard price, thereby reducing the quality of products to maximise their profits through importing low-grade or fake products, including fertilisers, pesticides and weedicides, which may not work on farmers' fields. Others repackage goods by diluting potent products such as pesticides, weedicides and fertilisers to increase volume and profit. This has resulted in violations of the recommended application rates by farmers, resulting in the environmental consequence of residues. Others import fake goods illegally through Ghana's borders to avoid paying government duties.

Syndicates can also seek to maintain their market share among farmers by setting up financial baits through the provision of extension services and inputs on credit. According to the respondents, firms that are reluctant to adapt to new survival strategies will collapse. Respondents were asked whether their companies would survive over the next five years. Out of 15 respondents, 73.3% (11 respondents) believed that their firms would not survive under Ghana's inflation environment. These 11 respondents explained that their firms would fail due to the depreciation of the domestic currency in relation to the dollar, the high cost of freight, competition with cheap and illegal imports through lax border controls from neighbouring countries, and not operating close to full capacity.

3.3.4.4 Government

Government intervention in the agriculture sector is the rule of the day in Ghana and other African countries. Public investment in agricultural research and extension services, along with a range of other support systems, have played a role in trying to increase productivity using traditional approaches in a failing system over the past 50 years. The patterns of Ghanaian government interventions lack both a systemic approach and an ecological orientation, and they are often dominated by short-term quick-fix considerations, including privatisation. Increasing the survival and growth rate of agricultural industries and food security requires more than good traditional interventions, which are often overridden and undermined by inappropriate agricultural, economic and trade policies. Farmers complained

that getting the attention of the MOFA's extension agents requires the ability to be able to reward them financially; thus, commercial farmers mostly benefit from extension services. MOFA agents also engage in illegal transactions such as hiring or selling their motor vehicles, which can transport them to farmers' fields. Government intervention in Ghana and most developing countries lies in the incentivising of weak structures. Market interventions are often ineffective due to a lack of organisational structure for procurement and distribution. Farmers are exposed to a high degree of uncertainty, and price support systems have often favoured peri-urban commercial crop farmers, leading to distortions in cropping patterns that add to the destructive pressures on the resource base.

3.4 Systemic Interventions Using the BBN

During the workshops to validate the BBN model, stakeholders identified and consented to all the nodes/variables of the BBN, for example, "improve structures" to induce perfect competition, "access to market information" for the structure of information flows (who does and does not have access to information), "government policies", access to "arable land" and "funding", as places within the system to intervene (Meadows, 1997) to leverage agribusiness survival and growth (Figure 5). Agribusiness survival and growth is affected by the interplay of the structure (number of farmers and traders, number of markets, quality and quantity of infrastructure support), conduct (production and marketing practices, including pricing) and performance (prices, quantities, profits and policies), as shown in Figure 3.5. The degree of effect is dependent on how the structure is improved, the way the conduct is regulated and the optimal utilisation of the resources employed. In general terms, this is performed by altering the states of some nodes, while observing the effect this has on others. As the BBN is a network, the effect of changing any variable is transmitted right through the network in accordance with the relationships expressed by the CPTs. Figure 3.5 outlines the current situation in the agricultural system in Ghana.
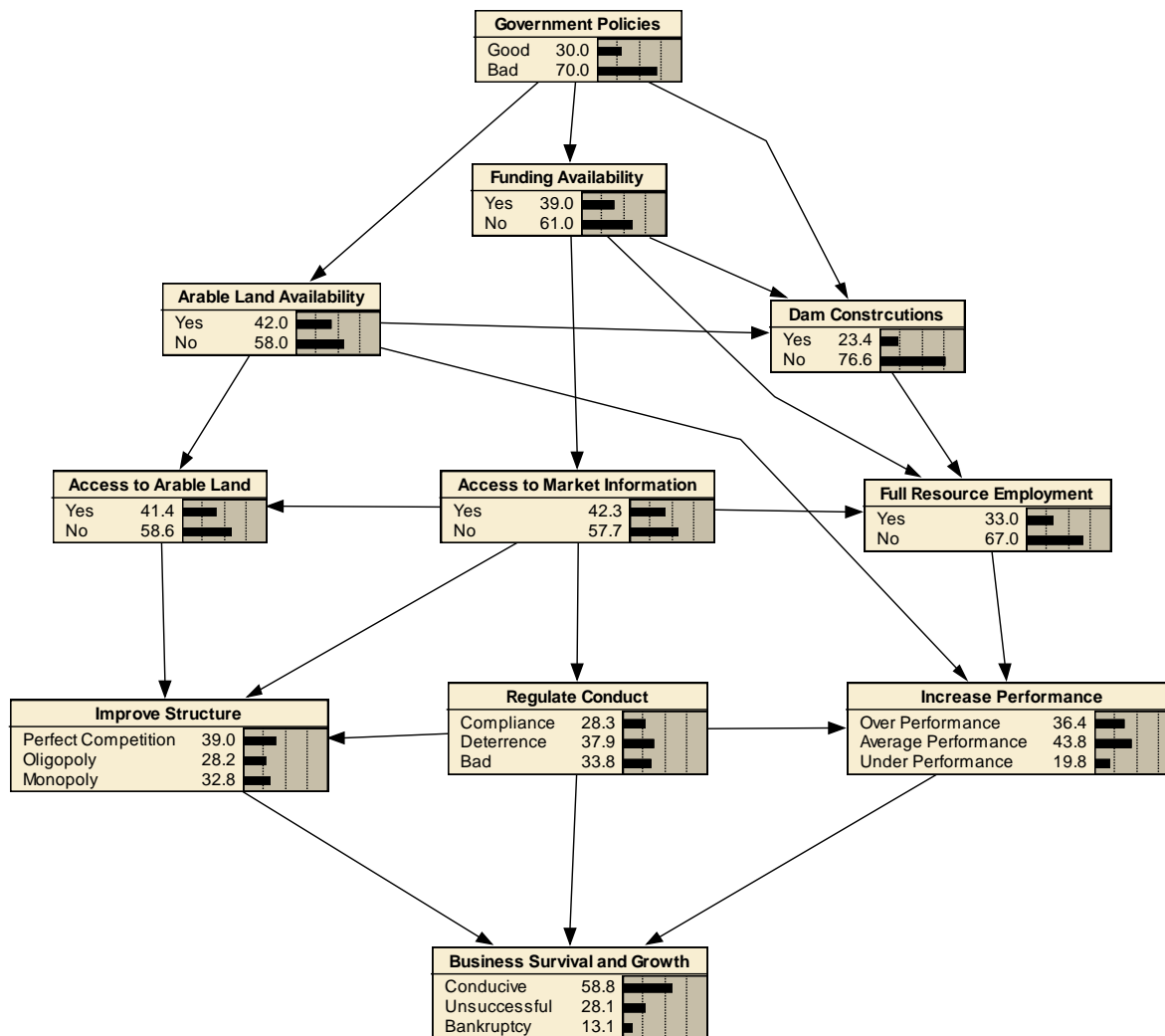
Figure 3.5: Bayesian networks showing factors determining business survival and growth (without intervention)

Figure 3.6 then shows how the probability that the objective (business survival and growth) is in the state of 'conducive' changes as the state of the interventions are changed. Stakeholders identified business survival and growth as their main objective and the construction of a dam as their preferred intervention. According to stakeholders, dam construction (intervention) would affect agricultural productivity and growth (business survival and growth). Stakeholders explained that this would happen due to an increase in water availability through improved surface water storage and increased groundwater recharge, although this would be dependent on rainfall. They also pointed out that dam construction would probably change the cultivatable area (both by removing land from production and potentially increasing irrigation command areas). Clearly the dam construction project would need funding to be implemented.

Funding and access to arable land and market information were the management interventions considered the most likely to achieve the objective (business survival and growth), as shown

in Figure 3.6. Here, feedback arises throughout the network from the interaction between the SCP, arable land availability, dam construction and full resource employment.
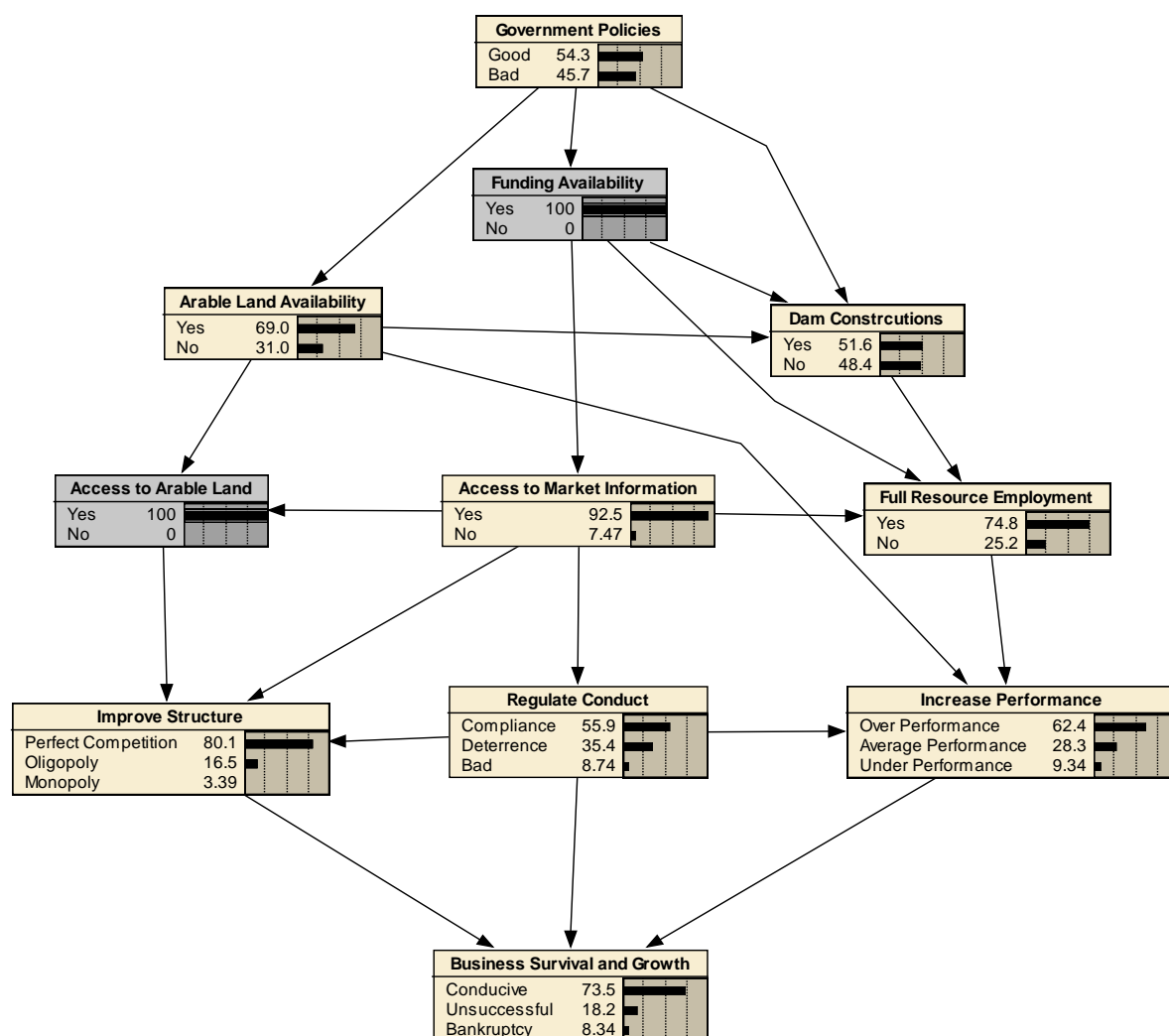
Figure 3.6: Bayesian networks showing factors determining business survival and growth (with intervention)

As the BBN is a network, the effect of changing these variables is transmitted right through the network in accordance with the relationships expressed by the CPTs. Figure 3.6 shows a 73% difference in the chance that business survival and growth will be conducive, depending on the state of 'access to arable land' and 'funding', which is from 58.8% conducive, as shown in Figure 3.5. Further, the possibility of constructing a dam increased from 23.4% to 51.6%. This in turn increased the chances of full resource employment and access to market information from 33% and 42.3% to 74.8% and 92.5%, respectively. These changes therefore led to a chance for improved structure (from 39.0% to 80.1%), high-conduct compliance (from 28.3% to 55.9%) and increased performance (from 36.4% to 62.4%), as shown in the 'before intervention' (see Figure 3.5) and the 'after systemic intervention' (see Figure 3.6) schemata.

3.5 Conclusion

Capacity building and governance using a systems dynamic approach and the ELLab in the SCP of the agribusiness industry has been proven to be effective in understanding complex design problems. Results from the BBN models indicated that the implementation of systemically determined interventions, policies and strategies could significantly improve the SCP and the rate of business survival and growth in the Ghanaian agriculture industry. These would also lead to a significant increase in the yield and profit of farmers and actors, reducing their negative means of survival that poorly affect the ecosystem. This approach could serve as a complementary tool for the Ghanaian and African governments and agriculture proponents to analyse and test the possible outcomes of different policy interventions by observing what would happen to the system as a whole before any time or money is invested in implementation. This will help eliminate or minimise the waste of scarce resources and unintended consequences associated with funding research and development.

This research presents an integrated mental model of a CLD of the SCP model of the agricultural system in Africa and explores how relationships within the structure of a system are influenced by its behaviour. The diagrams are more complete than any found in the existing literature. This model has provided insights into potential system behaviours and identified leverage points for the systemic interventions required to improve the performance of the agricultural sector in both Ghana and Africa as a whole. This approach will help governments, managers, scientists, decision makers and policymakers to anticipate the long-term consequences of their decisions and actions. It is crucial that researchers, policymakers and development practitioners understand the kind of feedback loops of the SCP model that assist in adaptive management and decision support.

This research provides a framework that will provide an understanding of the SCP changes in agricultural industries beyond the boundaries of traditional analysis. It also serves as a model to enable researchers and policymakers to move beyond the scope of traditional approaches and analysis to effectively deal with a wide range of contemporary issues affecting the SCP of the agricultural industry. Improving business survival and growth or stakeholders' competitive advantages by using systemic approaches throughout the industry will meet the needs of all stakeholders, including farmers, donors, governments, private companies and researchers. Thus, this approach will reduce the exploitation of the ecosystem that occurs with traditional approaches. It will also clarify the role of complex organisations in modern society and predict the complexity of organisations; therefore, the role of management will probably continue to increase—at least for as long as the efficiency-enhancing potential of complexity can continue to outweigh its inevitably increasing transaction costs. This will also initiate a

new era where many promising agricultural research and development initiatives could provide sustainable solutions to national and regional agricultural challenges in most parts of Africa. Developing communities must be convinced to take a fresh look not only at development itself, but also at the best mechanisms and models for achieving such development.

Systems thinking approaches foster maximum collaboration with all agricultural stakeholders (i.e., farmers, farmer groups/organisations, research scientists, agricultural extension agents, NGOs, private sector, development agencies and policymakers) in the industry. This will lead to robust outputs for multi-stakeholders. The ELLab approach coupled with Bayesian networks demonstrates the importance of making decisions with consideration given to how management choices will affect the environmental system in the future. Therefore, for CLDs and Bayesian networks to be useful tools, further research needs to be undertaken that considers this approach.

3.6 Acknowledgements

Chapter 4: Paper Three: System Archetypes for African Agriculture

■ Research Paper

Using System Archetypes to Identify Drivers and Barriers for Sustainable Agriculture in Africa: A Case Study in Ghana

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The African agricultural system is characterized by complex challenges such as famine, food insecurity, poor soil and quality standards, political instability, and inappropriate agricultural practices. The behavior over time graph revealed that as the African population increases, people explore new agricultural land that is in direct conflict with the conservation of forested areas, hence degrading the environment. These challenges in addition to the depletion of natural resources have worsened the plights of African farmers. The increasingly complex nature of the agricultural industry in Africa has necessitated an urgent need for the use of a systemic rather than a traditional approach in solving problems in agriculture. System archetypes were applied as diagnostic tools to anticipate potential problems and problem symptoms. Eleven system archetypes serve as the means for gaining insights into the underlying system structures from which the archetypal behaviors emerge. As part of a suite of tools, they are extremely valuable in developing broad understandings about agriculture and their environments and contribute to more effectively understanding the cause of a fix 'now' that gives rise to a much bigger problem to fix 'later'. The study revealed that opportunity and risk matrix as a policy tool does not solve the problems, but systemic approach would lead to the provision of the right management strategies. This approach facilitates adaptation and mitigation strategies towards the sustainable development for the agriculture in Africa. Copyright © 2014 John Wiley & Sons, Ltd.

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Name of Principal Author (Candidate)	Kwamina Ewur Banson		
Contribution to the Paper	The conception and design of the manuscript, establishing methodology, conducting workshops in the study area for data collection and models validation in Ghana. Compiling, analysing and interpreting data, working on the development of the first draft manuscript and the writing and submission of the final version.		
Overall percentage (%)	85%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	16/06/2016

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

 i. the candidate's stated contribution to the publication is accurate (as detailed above);

 ii. permission is granted for the candidate to include the publication in the thesis; and

 iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Nam C. Nguyen (Principal Supervisor)		
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Contribution to the Paper	Supervising and assisting with the establishing of methodology, editing and co-authoring the manuscript.		
Signature		Date	28/06/2016

Please cut and paste additional co-author panels here as required.

4.1 Introduction

Agricultural sustainability has its roots in ancient times, 'to leave the land to rest and to lie fallow for a year after 6 years of continuous cropping for the wellbeing of both man and the ecosystem' (Exodus 23:10–11 2011). Africa has evolved from leaving the cultivated land to fallow to continuous cultivation of the land to meet food demand and profit margins. Continuous cultivation has exposed the soil structure to the vagaries of chemicals and the destruction of the ecosystem, including human health. Recent studies have revealed that going back to green or organic production is relatively more profitable economically, and it is environmentally friendly compared to conventional methods (Delbridge et al. 2013; Rigby & Cáceres 2001). This has led to the rise of a sustainable agriculture movement (US and EU) as a result of the adverse effects of cultivation practices depleting non-renewable resources and posing a threat to the ecosystem and people's livelihoods (Buttel 1992; Rigby & Cáceres 2001; Tilman et al. 2002).

Sustainable farming systems centre on the need to manage agricultural lands with innovations and practices that favour the ecosystem and 'land re-use' in the future. This provides a better livelihood and improvements in food productivity (Francis, Flora & King 1990; MacRae et al. 1990; Neher 1992; Paulino 2014; Tilman et al. 2002).

Agricultural systems exhibit great complexity economically, socially, politically, culturally and environmentally. This complexity involves the interaction and interdependence of component parts to maintain the systems' stability or generate the exponential growth or collapse of the system. Thus, dealing with problems within the system using a traditional linear cause-and-effect approach fails to yield positive and long-lasting results. A new approach (systems thinking) is therefore urgently required to manage this complexity.

The application of systems thinking or dynamics to manage complexities has generated a broad array of tools, including causal loop modelling, behaviour over time graphs, stock and flow models, and systems archetypes. This approach provides an opportunity to test the potential effects of interventions that will ensure cost-effectiveness and affect maximisation. The application of systems archetypes to agricultural industries within Africa and around the world is one way of achieving these systemic interventions.

The increasingly complex nature of government and business has resulted in an increase in the use of a systemic research approach to solve operational problems (Petkov et al. 2007). This assumes a significant role in the formulation of economic policy for both the government and business. African governments currently have neither adequate information nor the necessary tools required to analyse the performance of policies affecting the food and

agricultural sectors. The local and global challenges currently facing the agricultural sector in Africa (including Ghana) are highly complex in nature. It has been demonstrated that these challenges cannot be addressed and solved in isolation and with the single-dimensional mindsets and tools of the past (Nguyen & Bosch 2013). Therefore, agricultural sustainability requires a systemic approach to interventions and capacity-building based on systems thinking and complexity management strategies to address challenges holistically and deliver high-leverage interventions for problematic system behaviour.

This paper explores the application of systems archetypes to serve as an effective tool for gaining insights into patterns of behaviour of the agricultural systems structure of Ghana. An archetype is a well-defined structure that exhibits distinct behaviour over time and has a well-defined strategy for dealing with the underlying structure of the system being studied (Braun 2002b). As governments formulate policies with which to accomplish the nation's flagship projects, the archetypes can be applied to test whether policies and structures under consideration may be altering the agricultural system in such a manner as to produce the archetypal behaviours desired. If governments find this to be the case, they can take remedial action before the changes are adopted and embedded in the complex agricultural system to avoid significant unintended consequences.

4.1.1 Complex Agricultural System of Africa

The agricultural system is an interactive and interdependent group of component parts that are linked to form a highly complex and unified whole that maintains the system's stability, exponential growth or collapse.

The agricultural system consists of the horticultural industry, cash crops (e.g., cocoa, coffee, cotton), livestock industry, fisheries and non-traditional agriculture (e.g., bee raising, mushroom production). These industries interact with the environment (soil, water and climate), people and other political and financial elements to form a complex agricultural system (see Figure 4.1).
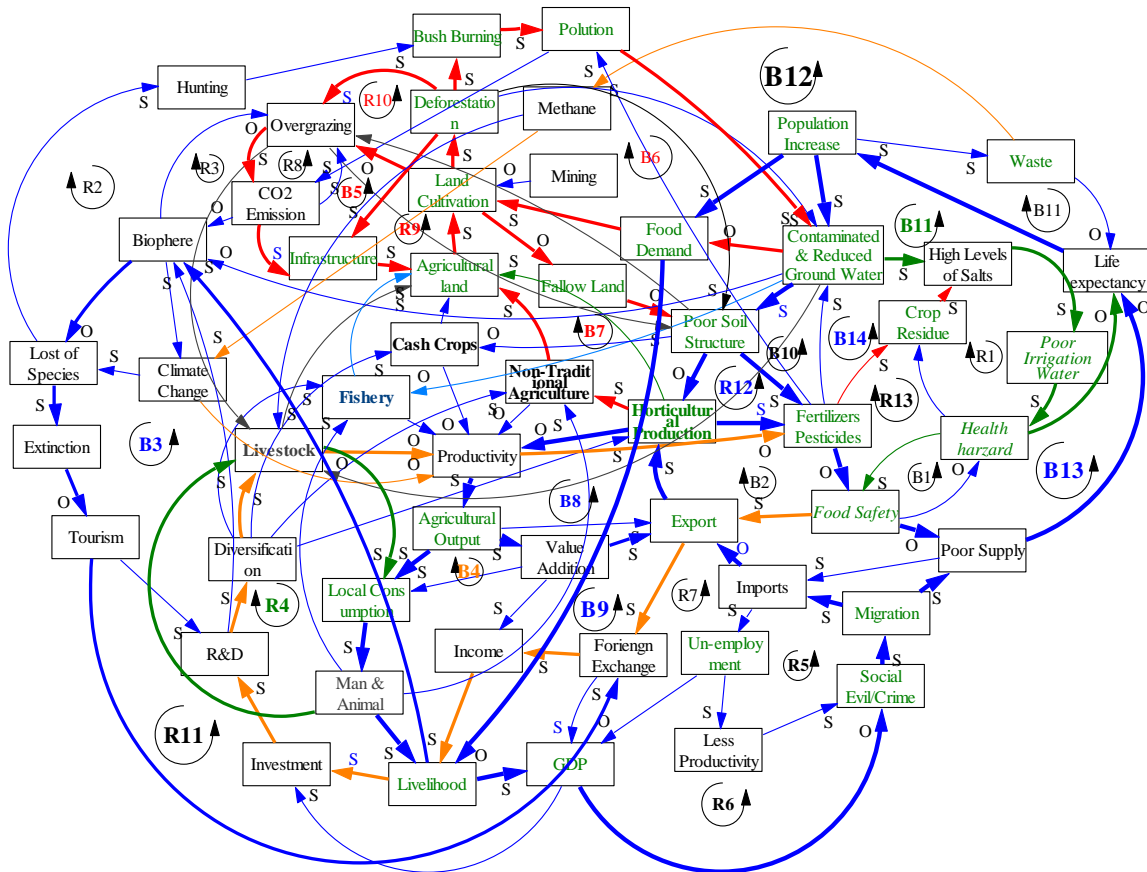
Figure 4.1: Agricultural systems web of Africa

4.1.2 Economic Importance of Agriculture in Africa

Agriculture employs 65% of Africa's labour force and accounts for 32% of gross domestic product (GDP; World Bank 2013c). Agriculture is essential for sub-Saharan Africa's growth and for achieving the Millennium Development Goal of halving poverty by 2015. However agricultural performance and growth are among the lowest in the world (World Bank 2013c). Agricultural GDP growth in sub-Saharan Africa has accelerated from 2.3% per year in the 1980s to 3.8% per year from 2000 to 2005. Growth has been mostly based on area expansion, but land is scarce and many countries are facing limits to further expansion.

Figure 4.1 illustrates that the components of complex agriculture systems are interconnected and interdependent on each other. The figure shows that negative practices, such as the uncontrolled use of excess fertiliser and pesticides in the horticulture and cash crop industries, raise the soil Ph. These salts are washed into underground and freshwater bodies and negatively affect aquatic life, wildlife and other livestock. Further, they negatively affect the whole system's structure and productivity, which affect GDP and livelihood in the long run.

Fruit, vegetables and nuts comprise Africa's $34.9 billion horticulture industry (International Food & Agricultural Trade Policy Council 2010). This industry forms a key economic activity in terms of foreign exchange earnings, fiscal revenues, income growth, employment creation

and livelihood sustenance for more than 800 million people who are dependent on the agricultural sector. However, agricultural practices and policies in the sector have also contributed to land degradation and the destruction of the ecosystem, with numerous challenges hindering its capacity to spur economic growth. Notable among these are climate change, increased pressure on the natural resource base, unfavourable external market conditions, poor rural infrastructure, weak institutions, low research and access to innovative technologies, low productivity of smallholders, reduced investment by governments and official development assistance, and limited engagement by the private sector (UNDP 2012b).

The increasingly complex nature of the agricultural system has raised concerns in governments and businesses to identify high-leverage interventions for problematic complex system behaviour. Over the past 6 decades, the World Bank and other development institutions have funded numerous projects and policy interventions and have provided technical assistance to support export growth, export diversification and the growth of value added in the agricultural sector (World Bank 2013c). In parallel, African governments are also considering restructuring agricultural sector policies to include new activities, such as a component to support agribusiness.

4.1.3 Behaviour over Time of the African Agricultural System

The behaviour over time graphs show that the elements of the systems are continually changing over time (see Figure 4.2). They show the system's elements (population, forest area, environment, agricultural lands, GDP and agricultural productivity) in the form of trends and patterns of behaviour in a system. In the early 1960s, the nature of agricultural cultivation in Africa began to change rapidly. Agricultural production has been increasing; however, productivity has generally been decreasing (World Bank 2013a). Although GDP is rising slowly, poverty (including nutritional food insecurity) is widespread in many of the less-favoured agricultural regions of Africa (Rasheed & DavisKristin 2012). For maintaining and improving the productivity of the agricultural system, the natural resource base needs to be sustainably managed. Figure 4.2 illustrates the behaviour over time of the African population, forest area, environment, agricultural land use, GDP and agricultural productivity from 1961 to 2011.
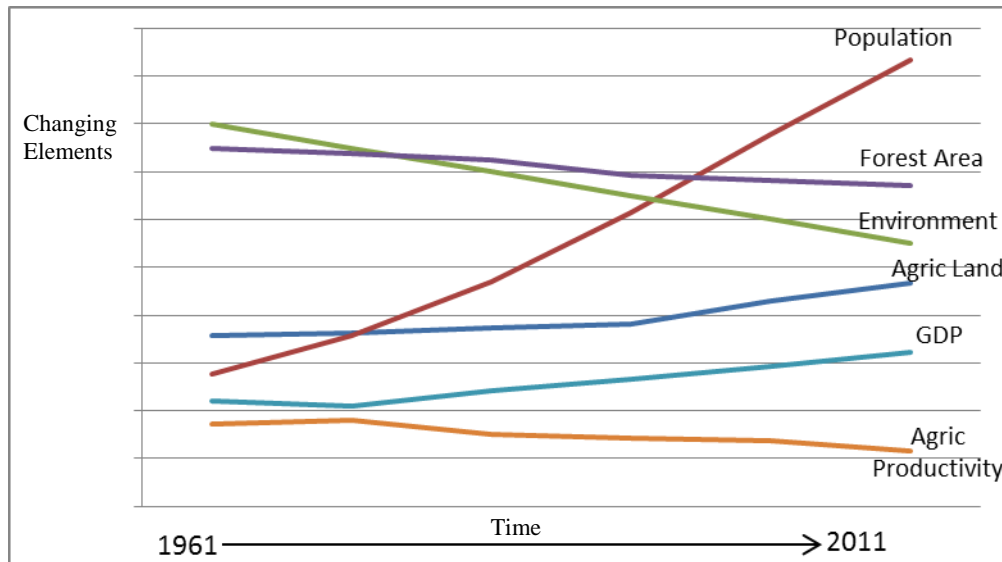
Figure 4.2: Behaviour over time of some key agricultural variables in the system

Figure 4.2 shows that despite substantial external migration and/or emigration, Africa's population continues to grow, and the majority of people still depend on agriculture, forestry or fishing for their livelihood. Agricultural land use as a result of cultivation and infrastructure (roads, car parks, buildings) development within Africa benefits agriculture by increasing agricultural lands and making available accessible roads to transport agrigoods. However, cultivation also disrupts microbiological activity and causes oxidation of organic matter, which can lead to soil structural problems such as surface sealing and hard-setting. When soil is capped with an impermeable layer, it effectively ceases to function as a biological entity. The consequences are more than a loss of land for agriculture, conservation and other uses. Capping soil changes the water balance of catchments (more run-off is produced from rainstorms over a shorter period) and reduces the area available for soil respiration and carbon sequestration. As a result, farmers turn to fertilisers and pesticides or explore new agricultural lands in forest areas, leading to the depletion of forested areas. It is interesting to note that as agricultural land increases, forests decrease. Figure 4.1 also indicates that as the use of fertilisers and pesticides increases, they contaminate underground water through run-offs, which have ripple effects on the whole system.

4.1.4 Pictorial Representation of the Complex Agricultural System

Figure 4.3 is a pictorial version of the agricultural system. Fertilisers, pesticides and herbicides, including banned ones, are still being used in Africa's cultivation. These substances move from the soil to the edible portions of plants and underground water, which persist and adversely affect both natural and manmade environmental resources (fresh water, clean air, forests, grasslands, marine resources and agroecosystems), as simplified in Figure 4.3.
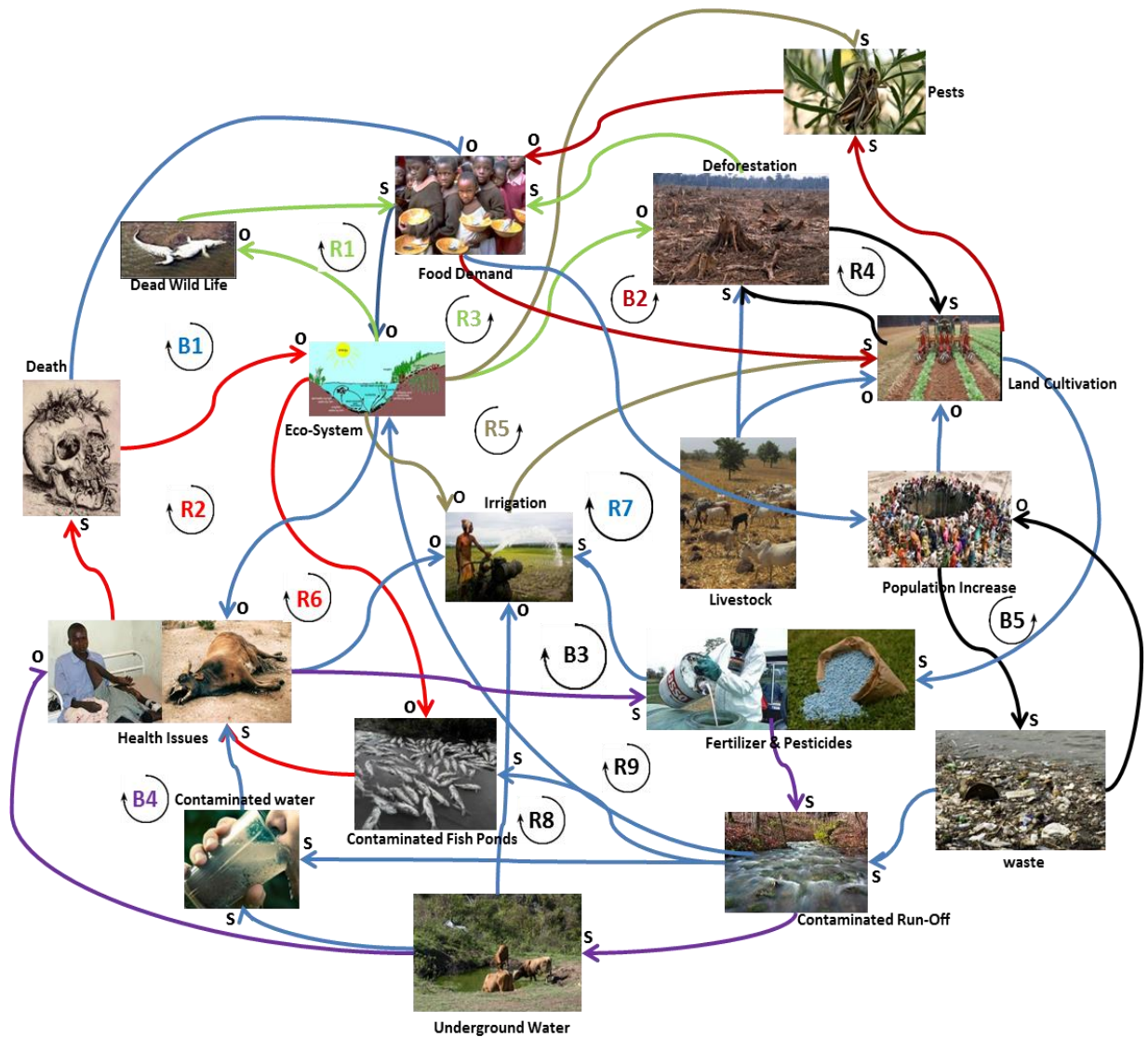
Figure 4.3: Pictorial agricultural systems

The environment provides sustenance and a foundation for social, economic and cultural development; thus, there is a need to safeguard these resources across all borders. The behaviour over time of Figure 4.2 shows that there has been a depletion of the environment since 1961. Declining nutrient-use efficiency, physical and chemical degradation of soil, and inefficient water use have been limiting crop productivity (Singh 2000). As a result, productivity of agricultural output has been declining in Africa, especially in Ghana (see Figure 4.2).

4.2 Case Study

4.2.1 Ghana's agricultural web

Ghana has a wealth of natural resources and ecological and biological diversity, both renewable and non-renewable. These include minerals such as gold, industrial diamonds, bauxite, manganese and forest resources, such as timber, non-timber forest products (NTFPs) and wood fuels. Other natural resources include wetlands, fisheries, agricultural lands and

water resources, which are useful for agricultural, industrial, household, recreational and environmental activities.

Agricultural land represents 52% of the total area of the country. The remaining 48% of non-agricultural land use includes forest reserves, wildlife reserves, unreserved closed forests, unreserved savanna lands, and lands for mining, settlements and institutional uses (EPA 2002).

The agriculture sector is the largest contributor to Ghana's economy in terms of its contribution to GDP (about 38%), and it employs 45% of the active population. It accounts for about 75% of the export earnings (Enu & Attah-Obeng 2013) and contributes to meeting more than 90% of the country's food needs (EPA 2002). The complex agricultural sector comprises five subsectors that are interconnected and dependant on each other: crops other than cocoa (63% of agricultural GDP), cocoa (14%), forestry (11%), livestock/poultry (9%) and fisheries (5%). It contributes to ensuring food security, provides raw materials for local industries, generates foreign exchange and provides employment and incomes for most of the population (especially those living in rural areas), thereby contributing to poverty reduction.

However, Ghana's agricultural system is plagued by complex challenges. Notwithstanding the external demand of meeting the standards of the International Organization for Standardization and maintaining market shares, it is plagued by famine, food insecurity (drought, pests, livestock diseases and other agricultural problems, corruption, political instability, poor soil fertility and extreme weather events), poverty and inappropriate practices, leading to the depletion of its natural resources and thereby worsening the plight of farmers.

The current problems in the agricultural industry are too complex and complicated to be solved using traditional techniques (Weaver 1948). The reasons include, but are not limited to, its exposure to economic, social, environmental, cultural and political forces, in addition to technologies that do not factor in unintended negative consequences on the environment. Moreover, these new problems cannot be handled effectively with the linear cause and effect or with the statistical technique of describing average behaviour in problems of disorganised complexity. These new problems and the future of the agricultural industries in the world depend on great advances in science with systemic interventions greater than the nineteenth-century conquest of problems of simplicity or the twentieth-century victory over problems of disorganised complexity. New approaches are needed to integrate existing and future knowledge to help manage complex issues. According to Braun (2002b), archetypes reinforce the distinction between understanding and knowledge. Knowledge—that is, the 'know-how' that policymakers rely on to make decisions—proceeds from the 'contained' parts of the

whole to the 'containing whole', while understanding proceeds from the 'containing whole' to its parts.

4.2.2 Current Agricultural Policy in Ghana

Through the MOFA, the Government of Ghana developed the Food and Agriculture Sector Development Policy (FASDEP I) to guide development and interventions in the agricultural sector. The first FASDEP I was formulated in 2002 as a holistic policy, building on the key elements of the Accelerated Agricultural Growth and Development Strategy (AAGDS), and with a focus on strengthening the private sector as the engine of growth.

However, a poverty and social impact analysis (PSIA) of FASDEP I concluded that the policies would not be able to achieve the desired effect. Therefore, the MOFA developed a revised Food and Agriculture Sector Development Policy (FASDEP II) that currently serves as the main framework for agriculture in Ghana. The policy seeks to achieve an average growth rate of 6%–8% per annum over the next four years through the achievement of the following strategic objectives:

- food security and emergency preparedness
- improved growth in incomes
- increased competitiveness and enhanced integration into domestic and international markets
- sustainable management of land and environment
- science and technology applied in food and agriculture development
- improved institutional coordination.

It is envisioned that these strategic objectives will be related to agriculture infrastructure development, crop and animal production, technological development and dissemination, marketing of agriculture produce, and provision of service. Table 4.1 provides a summary of the key challenges for the agricultural sector.

According to the UN Economic Commission for Africa (2013), African governments have failed to maximise the productivity of their agricultural sector by overlooking policies to maximise sectoral linkages. The application of the four levels of thinking model to Ghana's agriculture system was used to test whether policies and structures under consideration may be altering the agricultural system in such a manner as to produce the archetypal behaviours desired.

4.3 Research Approach

The combination of data obtained from Ghana, interviews and the literature review regarding the use of the four levels of thinking model (see Figure 4.4) provide an overview of the current structure and effect of management strategies on an agriculture system riddled with feedback loops. Data collection started by gathering the mental models of all stakeholders involved in the agriculture industry in Ghana during a workshop to revise the FASDEP II. Another workshop involving 75 participants was organised in November 2013 to analyse the systems' barriers and drivers to agricultural sustainability.
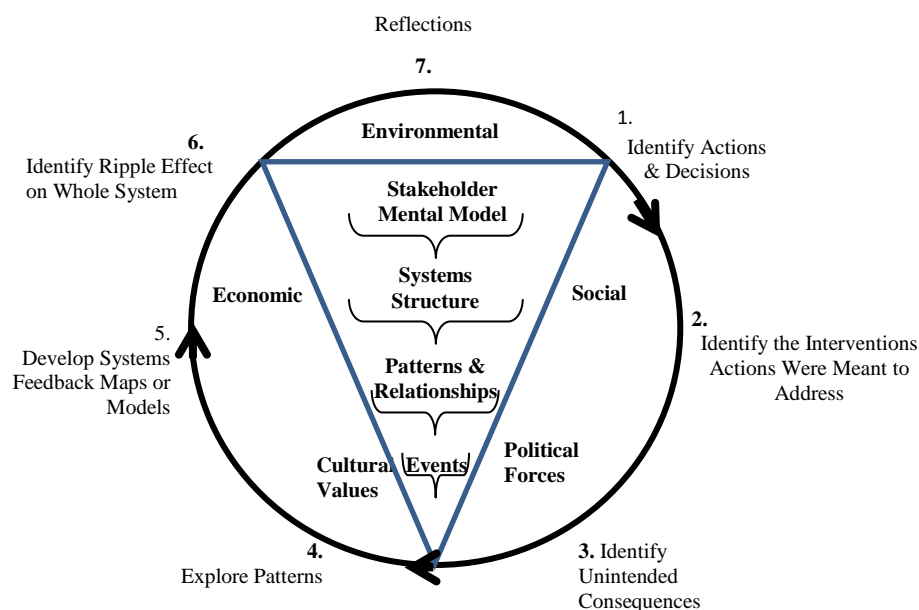
Figure 4.4: Feedback learning laboratory (adopted from Bosch et al. 2013)

The model starts at the 'first level of thinking', which involves a series of literature reviews and interviews with experts in the field (e.g., agricultural scientists and extension officers) to obtain the mental models of the policymakers behind the solutions provided to solve the challenges of the agricultural systems under deliberation. This was done by reflecting on the outcomes of the actions and decisions that have been implemented to determine their effect and identify significant unintended consequences and new barriers generated.

Once the unintended consequences and new barriers have been identified, the 'second level of thinking' is used to interpret and explore patterns and their interconnected components, and to analyse the kind of feedback loops, reinforcing loops and balancing loops that were generated.

This is followed by step three, which is the 'third level of thinking', in which the literature review was used to identify what pre-existing system archetypes were influencing the Ghanaian agricultural system. System archetypes are used to develop an understanding of interdependency and analyse the implemented strategies and/or policies that led to the

intervention effect. The Vensim software program (Ventana Systems UK) was used for the development of the systems archetypes of the issues under consideration. A CLD is the first step to modelling and simply converting the complex elements into a simple, easy-to-understand structure. CLDs are variables that are connected by key causal relationships to represent the reality used to display the behaviour of cause and effect from the system's standpoint (Toole 2005).

Finally, the 'fourth level of thinking' highlights the strategies needed to overcome the issues and challenges facing the entire complex agricultural system. Archetypes are useful for gaining insights into the 'nature' of the underlying problem and for offering a basic structure or foundation upon which a model can be further developed and constructed. Table 4.1 highlights the keys challenges/issues and policies of Ghana's agricultural systems.

Table 4.1: Key challenges and policies of Ghana's agriculture

No.	Agricultural related problems	Effect on the environment	Policies	Expected outcome/ consequences
1.0	• Bushfires • Pressure on land • Run-off/erosion • Over-grazing • Deforestation • Inappropriate land preparation and cropping system • Misuse of agrochemicals • Sand and gravel winning	Land degradation	• Access to land for agriculture • Access to farming inputs • Access to rural infrastructures • Cultivation of non-timber forest and wildlife products • Access to credit (e.g., seed, fertiliser)	• Ensure equitable distribution of lands to poor farmers • High-yielding and short-duration crop varieties • Improve accessibility and facilitate crop distribution • Storage facilities • Increased food security • Enhance private sector investments and participation in delivery of services and extension • Ensure sustained funding of research
1.2	• Poor fishing practices • Use of agro chemicals closer to water bodies • Improper disposal of household (liquid and solid), industrial, agro-processing waste	Pollution of water bodies	• Access to water for agriculture • Food safety & sanitation awareness raising • Human resource capacity and enhance training and research	• Ensure food access during disasters • Promote GAP, particularly for meeting sanitary and phytosanitary requirements of importing countries • Promote R&D and industrial use of indigenous staples and livestock
1.3	• Erosion • Bad farming practices along water bodies	Siltation of surface water bodies, dams	• Access to extension services • Increasing water quantity through irrigation schemes to provide more water • Disaster management schemes	• Disseminate technology and information • Irrigation schemes to ensure production throughout the year • Establish strategic stocks to support emergency preparedness

No.	Agricultural related problems	Effect on the environment	Policies	Expected outcome/ consequences
				• Strengthen early warning systems
1.4	• Destruction of water shed (destruction of vegetation, farming close to water bodies)	Global warming (greenhouse gases) Adverse climatic change	• Provision of wells and boreholes to supply quality water	• Provision of quality water for the poor
2.1	• Customary law practices • Frequent change of land ownership does not encourage cultivation of tree crops	Land tenure system	• Education and extension activities	• Promote and demystify cultural beliefs and practices (land tenure)
2.2	• Game hunting, wild honey tapping, charcoal burning, cigarette smokers, herdsmen, uncontrolled burning	Annual bush fires	• Bushfires disaster management schemes • Reduction in use of NTFP (medicinal plants)	• Reduce the tide of bushfires • Prevent the destruction of medicinal plants through forest clearing
3.0	• Unemployment • Diminishing sources of alternative livelihoods	Destruction of land by mining operators and illegal miners (galamsey operators)	• Diversification/alternative livelihoods	• Enhance access to productive resources. • Support diversification based on their comparative and needs to create employment
3.1	• Infrastructure Development in terms of modernisation	Sand and gravel winning for road & building constructions	• Access to health services • Minimise noxious gases and dust from the construction of roads • Promote collaboration	• Enhance access to health facilities and information • Improve air quality • Promote linkage of farmers to industry • Promote farmer-based organisations

The following tools were used to analyse the FASDEP II to achieve the policy objectives presented in Table 4.1 in the preceding texts. These included:

- a compatibility matrix to ensure internal consistency in policy objectives
- a compound matrix to evaluate policy objectives from the standpoint of poverty and the environment
- opportunities and risks matrix to assess policies in terms of their risks and opportunities related to the environment and poverty arising from implementation
- priority matrix to identify and strengthen priority policy actions, which creates a win–win situation for the rural/urban poor and the environment, increases understanding of

the spatial dimension of policies and their effects at international, national, regional and district levels, and analyses the effectiveness of policies in terms of ease of implementation, timescale and their ability to provide rapid benefits to the poor and the environment.

4.4 Systems Archetypes

The systems archetypes do not describe any one problem specifically; rather, they describe a spiral of problems generically (Braun 2002b). Their value comes from the insights they offer into the dynamic interaction of complex systems. This approach illustrates one's understanding of a particular system's structure and behaviour, which foster communication and identification of high-leverage interventions for problematic complex system behaviour. According to various scholars (e.g., Senge 2006; Maani & Cavana 2007; Nguyen & Bosch 2013), systems archetypes provide a high-level map of dynamic processes that reveal the simplicity underlying the complexity of management issues. They also reveal different leverage points to overcome difficult challenges. In addition to the obtained data, the FASDEP (FASDEP II) of Ghana was used as a policy study to generate the relevant systems archetypes.

Three systems models—horticulture, livestock and fisheries—in addition to six systems archetypes were identified in the complex agricultural systems model of Ghana. The archetypes included two 'limits to growth', 'success to the successful', 'escalation', 'accidental adversaries' and 'tragedy of the common'.

4.4.1 Systems Archetypes of the Horticultural Industry

Figure 4.5 illustrates the dynamics and reveals the interlinkages and interdependencies of the key components of the horticultural system. Each component mutually interacts and influences other parts over time to maintain the system's existence. Components can cause and affect the system in the same (S) or opposite (O) direction. The systems model of the horticultural industry is analysed by identifying the feedback loops formed in the model (Nguyen & Bosch 2013). Feedback loops can be reinforcing or balancing. The feedback loops identified in this model include 10 reinforcing ('R') and nine balancing ('B') loops.

Figure 4.5 illustrates that an increase in horticultural production leads to foreign exchange and a higher acquisition of agricultural land, which is in the same direction as deforestation. Further, food demand as a result of population increase is in the S direction with encroachment or intensive utilisation of agricultural lands, which is in an O direction with fallow land, which leads to the depletion of the soil structure. This indicates that a small

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change in one component structure (e.g., population triple down) negatively affects the ecosystem, which eventually affects the population or lives of living organisms.
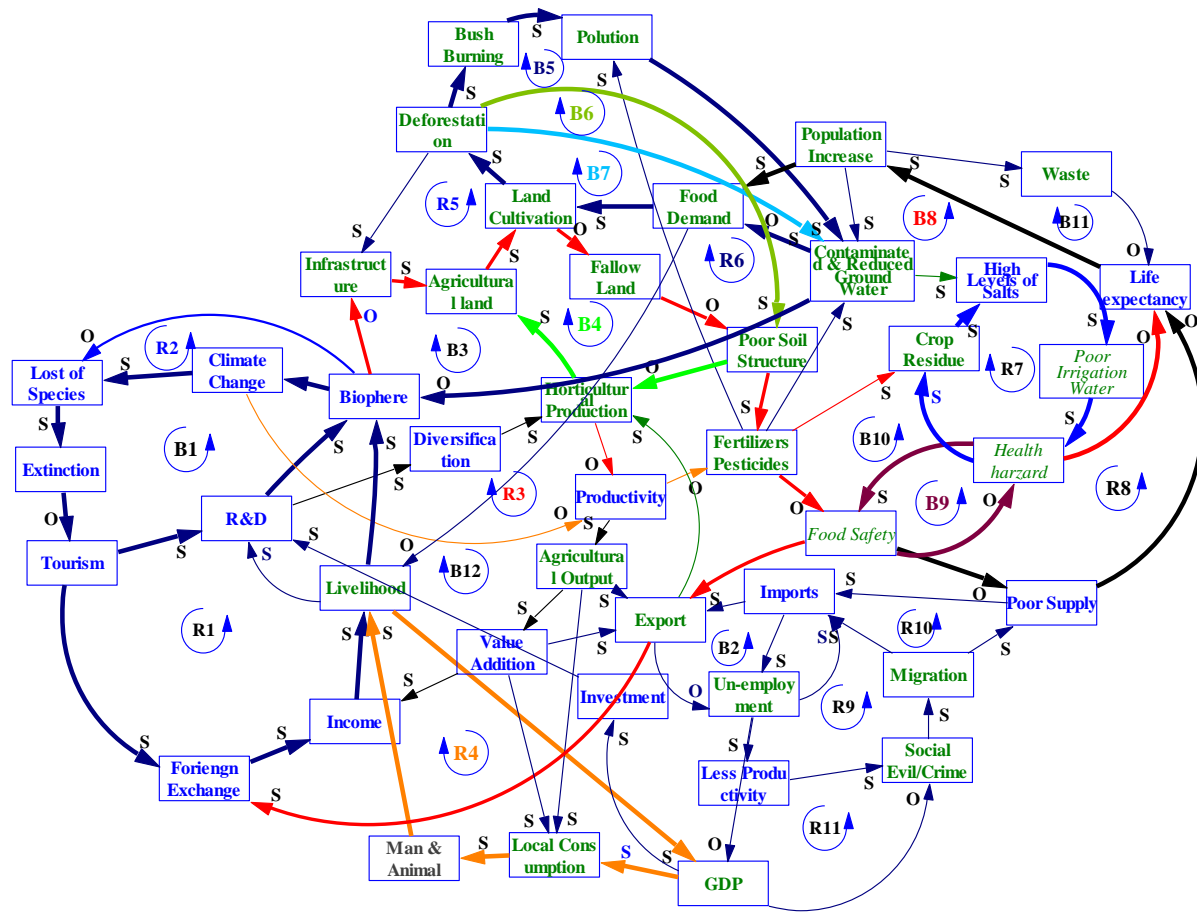
Figure 4.5: Horticultural system

Major linear adjustments at policy levels have been made in the agricultural systems at both the national and international levels to create conditions for sustainable agriculture and rural development in Africa, but this will not yield any long-term solutions or effects, as systemic intervention was not taken as an approach. Ghana's agricultural policy aimed at improving food security, increasing employment opportunities, significantly reducing poverty and accelerating agricultural growth and development with GDP growth of at least 6%. This study reviews Ghana's agricultural policy in relation, *inter alia*, to horticultural and fishery policies, agricultural subsidies and taxes, and organisation for regional economic integration.

4.4.1.1 Shifting the Burden

According to Braun (2002b), 'shifting the burden' is the first of several archetypes that illustrate the tension between the attraction (and relative ease and low cost) of devising symptomatic solutions to visible problems and the long-term effect of fundamental solutions aimed at the underlying structures that produce the pattern of behaviour in the first place.
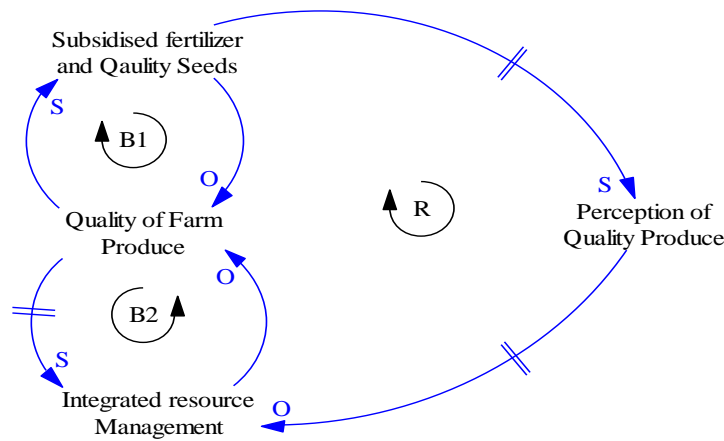
Figure 4.6: Shifting the burden systems archetype

The quality of crops produced is an issue in Ghana and other African agricultural industries and largely determines the share of the international market. This problem is a result of the depletion of good soil structures, resulting in poor fertility (Kumar & Goh 1999). The management practice in Ghana consists of providing government support to some farmers through subsidised fertilisers and quality seeds to help improve the quality of their produce (Bertow & Schultheis 2007).

If the problem is perceived as a lack of soil fertility and poor-quality seeds, then subsidising fertiliser and quality seeds is an apparent quick fix because it will lead to a good yield and provide security of quality in the short run (see Figure 4.6). This solution is much timelier than the longer-term solution of conducting integrated resource management, wherein the whole agricultural system is taken into consideration, thus enabling systemic interventions.

The side effect of this approach is that farmers will use these inputs, see good yields and develop a perception of produce quality, thus reducing support for conducting integrated resource management.

4.4.1.1.1 Strategies

Policies must specify if they are treating the symptoms (poor fertility) or addressing the root cause of the problem (depletion of good soil structures). The most effective strategy for dealing with a 'shifting the burden' structure is to employ the symptomatic solution and then develop the fundamental solution. Thus, one resolves the immediate problem and the other works to ensure that it does not return.

4.4.1.2 Limits to Growth

The 'limits to growth' structure consists of a reinforcing loop, the growth of which, after some success, is offset by an action of a balancing loop (see Figure 4.7).

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Ghana's agricultural industry has lost its market share as a result of production and post-harvest losses that resulted from chemical residues. In an effort to both recapture their eroding market share and find new markets, the Government of Ghana subsidises fertiliser and imports more pesticides, flooding the market with cheap and accessible fertiliser and pesticides. In the short run, produce quality improved and post-harvest losses were controlled, thereby increasing export success to the extent that the residues began to accumulate in produce and led to more ban of produce exported.
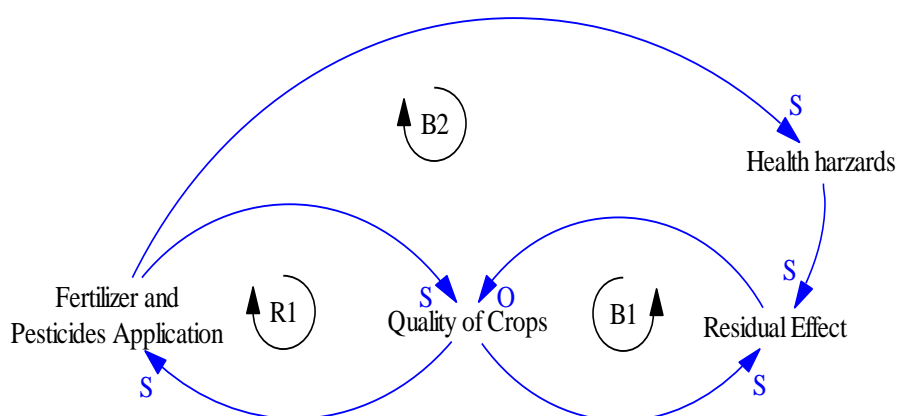
Figure 4.7: Limits to growth systems archetype

4.4.1.2.1 Strategies

The limiting factor in the reinforcing loop operating must be removed (fertilisers and pesticides application) before it has a chance to create a substantial effect on the quality of crops. These strategies will adapt to farming lands, which depict excessive residues in fertilisers and pesticides. Implementation may be a complex process, as it may require a number of steps. Strategies may also require a degree of timing to be successful, such as deciding the best time of year to launch a new ad campaign. Adopting the use of organic fertiliser to revert the residual lands and integrate pest management practices may avoid short-term difficulties for benefactors such as farmers and exporters. A change in the limiting factor will cause the ripple effects of change throughout the whole agricultural system. Policies must be instituted to implement the revised strategies. All stakeholders may not agree with the new strategic direction. They may resent the new interventions given because they may slow or reduce their profitability and, as a result, they may not make the maximum effort required for the new strategies to succeed. Part of the MOFA's responsibility will be to convince all members in the organisation that the changes will benefit everyone in the long run. If the MOFA communicates the reasons behind the change in strategy, resistance can be minimised and stakeholders are more likely to support the decisions that are made. Effective communication can achieve success through initial awareness creation and education in

interconnected thinking with stakeholders and in schools with students who may go on to become farmers, leaders and decision makers.

4.4.1.3 Success to the Successful

The 'success to the successful' archetype describes the common practice of rewarding good performance with more resources in the expectation that performance will continue to improve.
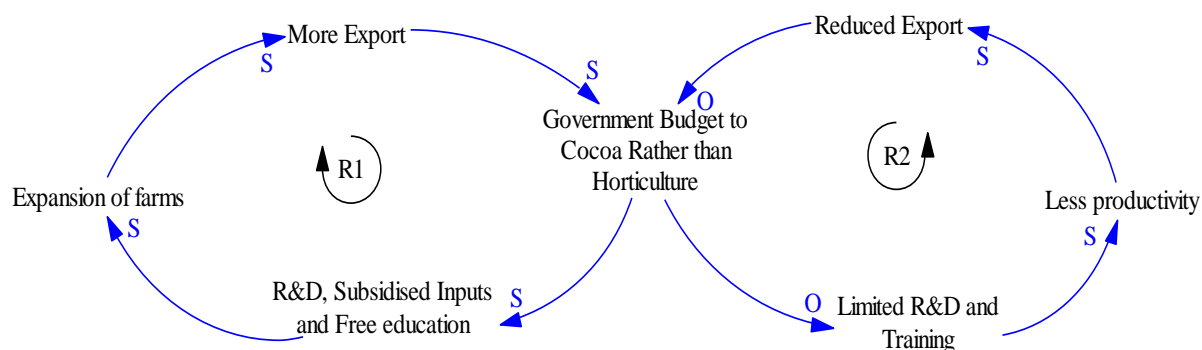
Figure 4.8: Success to the successful systems archetype

There is a belief that cocoa production and exports in Ghana have 'earned' their increasing share of resources through past performance (see Figure 4.8). The cash crop sector—especially cocoa and the horticultural sector—are established in different parts of Ghana. Some rationale for resource allocation results in the cocoa sector experiencing better performance than the horticultural sector. The success to the successful structure is at the heart of so many self-fulfilling rules, which are actually the results of unperceived influences on our own part.

4.4.1.3.1 Strategies

The horticultural and cocoa sectors must be disconnected so that they are not dependent on the allocation of resources based on their performance. Currently, the government is yet to commit a minimum allocation of 10% of its national annual budget to the agricultural sector, as agreed upon during the Maputo Declaration (African Union 2003). Thus, transferring or decreasing resources from the already underinvested cocoa sector to the horticultural sector will affect cocoa productivity. Disconnecting the sectors will also prevent the horticultural sector from being eroded, as the resources generated from it cannot then be diverted to improve the cocoa sector. According to Braun (2002), this archetype suggests that success or failure may be more because of initial conditions than intrinsic merits. It can help organisations challenge their success loops by 'unlearning' what they are already good at in order to explore new approaches and alternatives. The resource being unequally distributed must be brought into balance.

4.4.1.4 Escalation

In the agricultural export-oriented industry—especially involving an international market—it is not uncommon for competitors to engage in innovations as a tactic for securing market share. Each industry is seen as a threat by the competitor who, after some delay, will respond in kind.
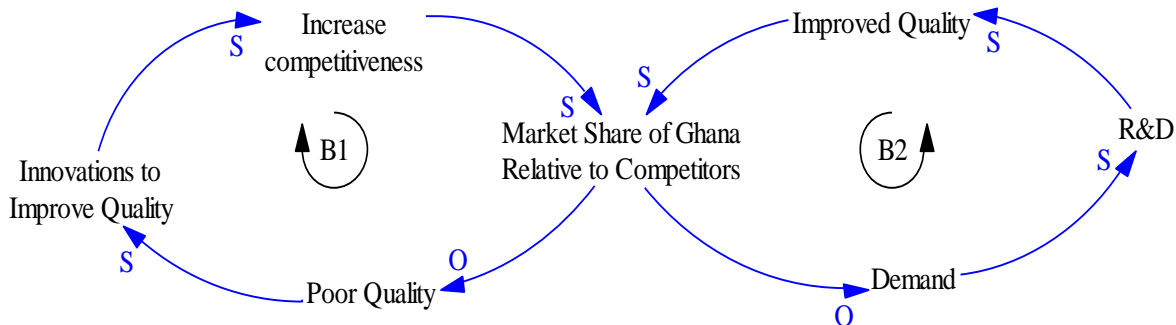
Figure 4.9: Escalation systems archetype

A commonly held belief of competition is mounting an appropriate response to the actions of competitors to sustain one's own competitive advantage and maintain momentum towards gaining a competitive advantage. This can continue for some time, until the cost of doing so becomes prohibitive and the escalation stops. This may result in one competitor's eventual market dominance (if it had the resources to support research and development) or in one competitor's collapse due to overextending itself financially (see Figure 4.9).

4.4.1.4.1 Strategies

The approach is to begin evaluating the composite results of both competing countries rather than focusing on their individual results. In this way, they begin to see the value in cooperation rather than competition, and the structure will turn into two synergistic reinforcing loops.

4.4.1.5 Accidental Adversaries

An out-grower scheme is when agricultural production is carried out according to an agreement between a buyer or exporter and farmers. Developing out-grower nucleus schemes is a sure way to increase the agriculture productivity of small-scale farmers by exporters.
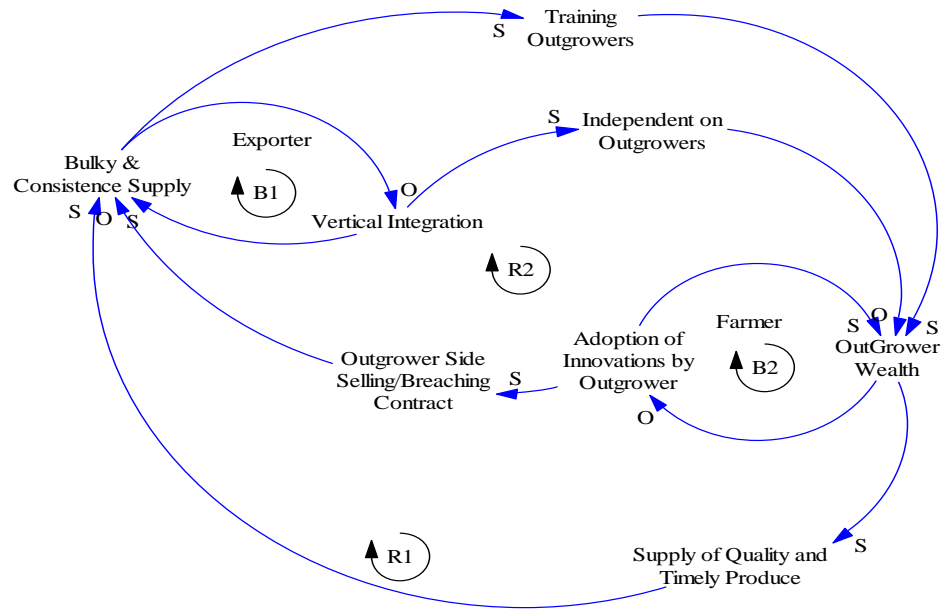
Figure 4.10: Accidental adversaries systems archetype

This strategy may reduce competition and increase market share by using economies of scale. Typically, the farmer agrees to provide established quantities of a specific agricultural product and meet the quality standards and delivery schedule set by the exporter. In turn, the exporter commits to purchase the product, often at a predetermined price. In some cases, the exporter also commits to support production through, for example, training, supplying farm inputs, land preparation, providing technical advice and arranging transport of the produce to the exporter's premises. With this scheme, farmers often have improved access to assured markets and prices (lower risks) with relatively higher returns (see Figure 4.10).

Initially, the relationships fared well. However, when performance and growth lagged as a result of exporters using their bargaining clout to their financial advantage, out-growers became uneasy with the relationship and began to interpret every move by the exporters as potentially (or actually) injurious to their interests. Common contractual problems included farmers selling to a new buyer other than the one to whom they were contracted (side selling or extra-contractual marketing); the result was the downward spiral of both parties' interests.

4.4.1.5.1 Strategies

This structure points out how narrow-minded local activity, with the best of intentions, can lead to an overall limiting development of the global system, and actually inhibit local development as well. Exporters and out-growers need to determine whether it is better to be partners in creating the future, and then focus on the goal of their relationship. An out-grower receives a range of potential benefits through partnerships with exporters. While some exporters offer out-growers a guaranteed market for their products—either at fixed, indexed or market prices—other exporters promote partnerships with the additional benefit of a

percentage share of the produce (e.g., pineapples) at harvest. Other arrangements offer employment or contribute to community development (e.g., funds for school or health facilities) or agricultural improvements. On the whole, contractual agreements to out-grower partnerships can be a mechanism for addressing several important issues for sustainable agricultural production. However, out-grower partnerships require consideration of how farmers can make use of the gains in agricultural production against the losses. Typically, farmers need a regular alternate source of income to avoid cash flow difficulties during production and dependence on loans. Out-grower arrangements that cause farmers to displace food crops with fruit tree production can jeopardise food security and force households to generate higher incomes to purchase food—all of which can expose households to greater socioeconomic risks.

4.4.2 Systems Archetypes of the Livestock Industry

Figure 4.11 provides an 'overview' of the livestock industry in Ghana. The savanna of Ghana carries most of the livestock population. The 1996 estimated figures for the various ruminant livestock species were: cattle, 1.25 million; sheep, 2.4 million; goats, 2.5 million (LPIU, 1997). The Upper West, Upper East and Northern Regions, which constitute the northern savanna, hold 74.4%, 36.5% and 43.4% of the national livestock respectively.

The livestock (cattle, sheep and goats) population density per km^2 in 1996 was 130 in the Upper East Region, 33 in the Upper West Region and 16 in the Northern Region (NAP, 2002). The Upper East Region is the most vulnerable to desertification and has the highest livestock population density. In many instances, three or four regions accounted for more than 50% of the livestock population types in the country.

4.4.2.1 Tragedy of the Commons

The 'tragedy of the commons' is that the common pasture and water banks are not regulated and are abused by some livestock farmers. Livestock herdsmen of Ghana, in addition to nomadic Fulani cattle herdsmen, overgraze a common pasture without constraint. The same applies to water, with grazing areas open to all who live around the water. The problem is that each herdsman puts as many animals on the commons as he or she can afford or raise, thereby increasing their own wealth until the commons is overgrazed and destroyed (see Figure 4.12).
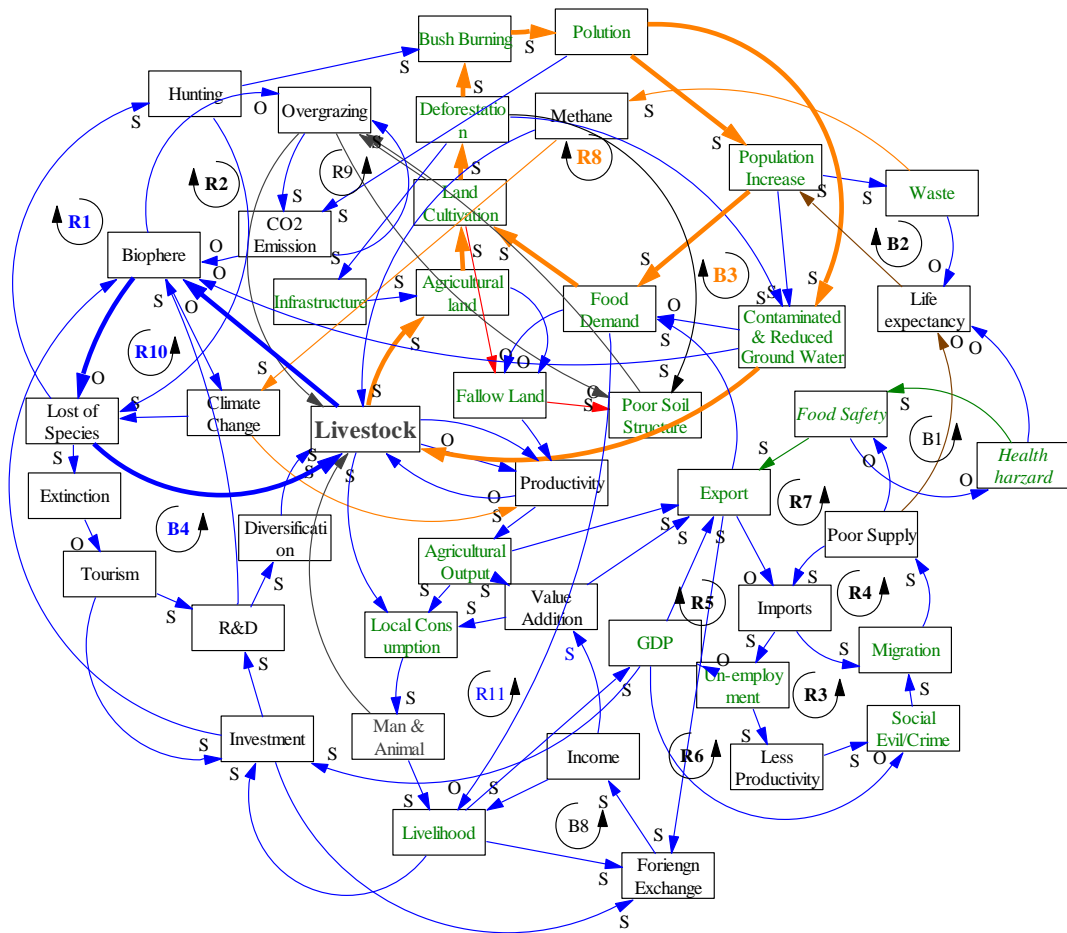
Figure 4.11: Livestock system
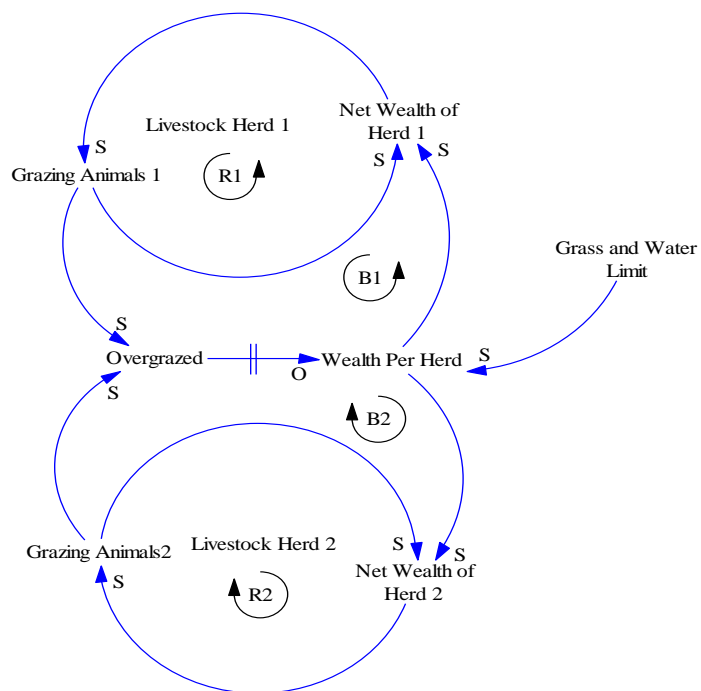
Figure 4.12: Tragedy of the commons systems archetype

Some herdsmen go to the extent of blocking water bodies in order to water their livestock, and these bodies of water eventually dry out. This tragedy can only be averted if the herdsmen cooperate in some form and regulate themselves. The distribution of livestock over the country can be explained in terms of the appropriateness of vegetation type and the presence or absence of tsetse fly. The savanna zones of the northern and coastal areas constitute the main areas where natural pastures abound for livestock farming. However, the pasture is deficient in many vital grass and leguminous species, with the result that its carrying capacity is extremely low—one animal to approximately 3–5 ha.

4.4.2.1.1 Strategy

The most effective strategy for dealing with these issues is to tax herdsmen A's result and herdsmen B's result to replenish and improve the commons or resources so that as A and B use resources, their tax promotes replacements and the availability of additional resources.

4.4.3 Systems Archetypes of the Fishery Industry

As a result of stagnation in marine or freshwater catches and an increase in fish demand and consumption, the commercial production of tilapia started in Ghana. Fisheries and aquaculture play an important role in providing food and income in Ghana (see Figure 4.13) and many developing countries, either as a standalone activity or in association with crop agriculture and livestock rearing (Allison & Hobbs 2006). The fishery sector in Ghana is wealth investment, especially with tilapia fish production in freshwaters. After seeking diversification, many businesses have chosen to invest in the fishery sector.

4.4.3.1 Limits to Growth

Most fishing businesses have grown very quickly and cannot grow further because of limits to growth and underinvestment in capacity. Most companies are unable to cope with growing demand, resulting in poorer product quality and longer delivery time, which means the greater the investment input, the greater the constraint becomes.

Various fixes have been explored to improve service performance. The long-term solution is to expand capacity proactively. This requires substantially more capital. Waiting for accumulated profits is difficult, and it becomes necessary to add investment partners. Seeking out proposals from interested parties requires time and effort. In the meantime, the short-term solution is to get the workforce to do overtime. In the process, most companies shift the burden between long- and short-term fixes. Fatigue from the sustained duration of overtime begins to cause more service failures, and many good staff members resign to join competing companies. Therefore, overtime production needs to be re-evaluated (see Figure 4.14).
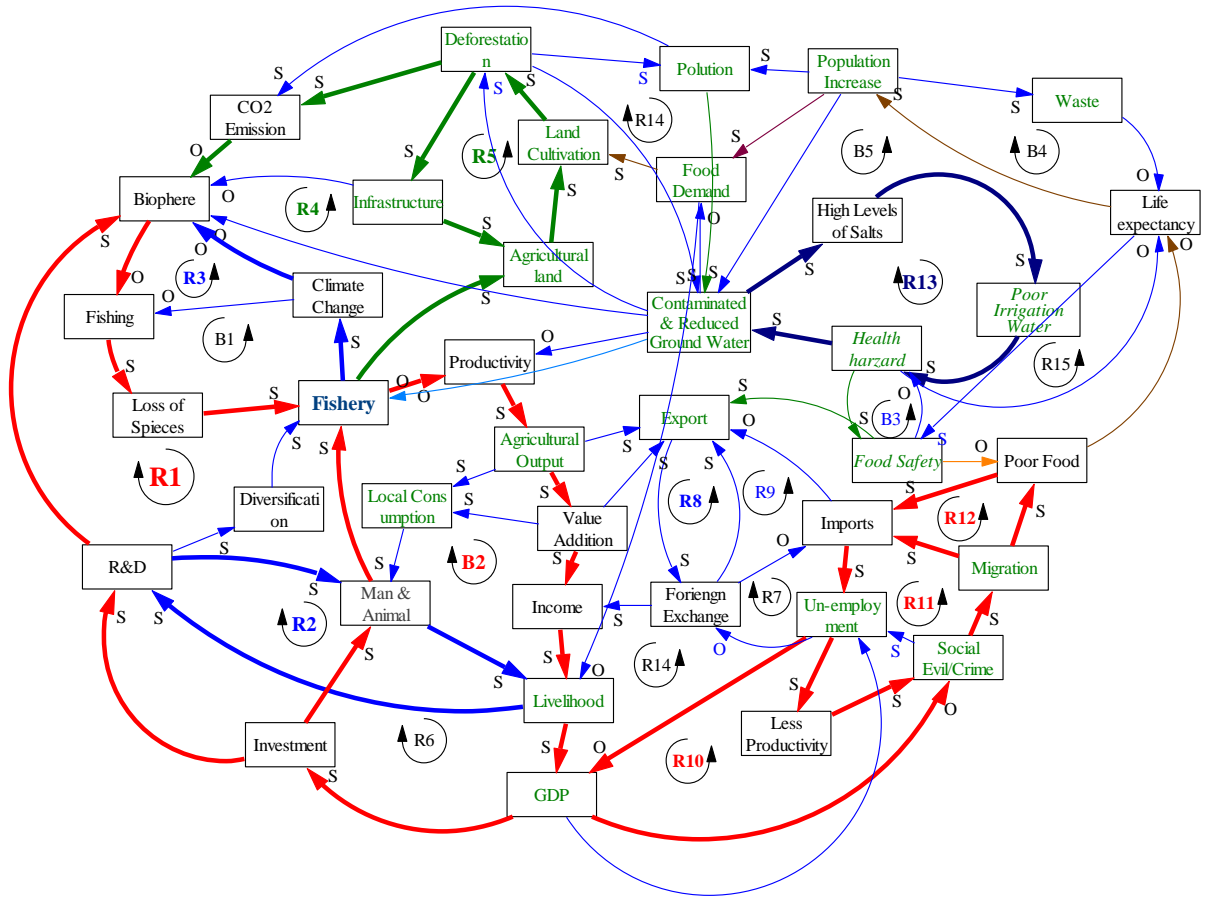
Figure 4.13: Fishery system
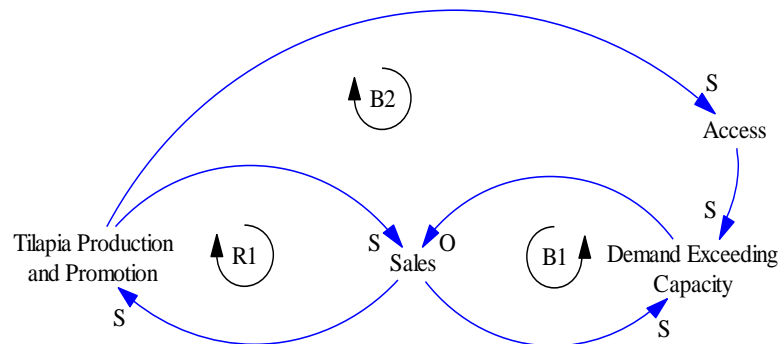
Figure 4.14: Limits to growth systems archetype

4.4.3.1.1 Strategies

The limiting factor in the reinforcing loop must be removed (reducing demand) by encouraging selective de-marketing strategies. This involves higher prices, scaling down of advertising and product redesign within segments of the markets among specific types of consumers before de-marketing has a chance to create a substantial effect on tilapia production. For example, what would be the reaction of tilapia farmers to consumers' sensitiveness towards the health implications of tilapia due to pollution (Rao, Perrino & Barreras 2012)? The pollution information on tilapia will create a negative health implication in the mind of the customer, who will hesitate to pay a price premium for the tilapia. This type

of de-marketing is necessary when there is a limited supply of tilapia and very strong demand. However, Lawther, Hastings and Lowry (1997) argue that classifying customers into desirable and undesirable may result in ethical questions being raised and may be interpreted as discrimination.

The challenge for tilapia farmers is to eliminate the demand or encourage customers to accept substitutes without losing their goodwill. Producers will also encounter low-price premiums in the market, and their profits may decline, which will make them hesitant to adopt this strategy. Reducing the level of demand will enable tilapia farmers to reduce the pollution level in the pond by reducing the intensity of the tilapia culture.

The government should encourage aquaculture and research institutions to develop technology to help ensure better production of quality and standard products—for example, novel ways to store fish in the current conditions of unstable electricity supply without the use of chemicals. This will reduce demand for fresh tilapia and encourage value addition, which can boost tilapia farmers' profitability. This is necessary to reduce the cases of food poisoning that usually occur when fishers try to store their farm products using excessive amounts of pesticides and other chemicals.

4.4.3.2 Success to Damage Archetype

The new 'success to damage' archetype was discovered in the Ghanaian agricultural industry. The activities of food crop farmer 'A' eventually negatively affect the activities of fish farmer 'B' downstream. The 'chemical inputs' residuals that the food crop farmer applies in order to improve his or her margins may poison the health of the fishpond and result in the fall of the fish farmer's business. In the long run, this decreases productivity and affects or leads to the fall of both farmers (see Figure 4.15).
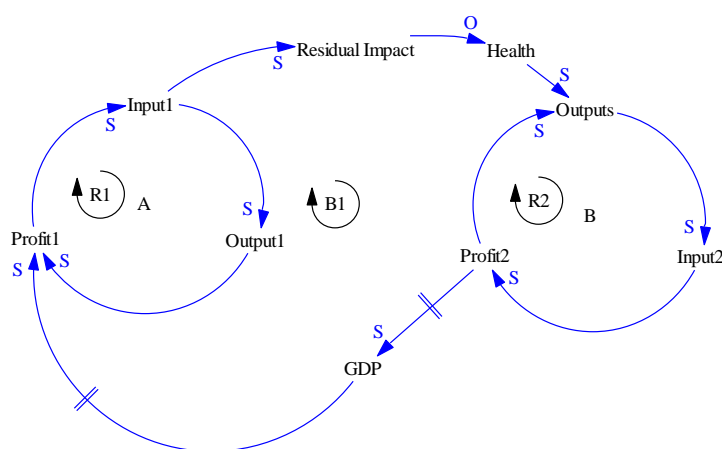
Figure 4.15: Success to damage systems archetype

This system archetype can be found in the agricultural export industry and the drug manufacturing industry, where excess chemical residues affect the health of consumers, which eventually leads to unproductiveness as a result of poor health and decreases the overall productivity of the nation, which leads to less investment in both sectors.

4.4.3.2.1 Strategies

The limiting factor in the reinforcing loop (R1) must be removed (chemical input) by encouraging organic methods. Farmers should be made to pay the full consequences of their actions by law.

4.5 Conclusion

The systems archetypes revealed insights into the agricultural structure that already exists to anticipate potential problems and problem symptoms. As part of a suite of tools, they are extremely valuable in developing broad understandings about agricultural industries and their environments, and they contribute to more effectively understanding the root causes of challenges rather than a fix 'now' that gives rise to a much bigger problem to fix 'later'. Unlike the opportunities and risks matrix, the compatibility matrix, the priority matrix and the compound matrix tools that analysed policies based on the symptoms of the problems, the systemic approach provided complex maps that revealed the interconnectedness, dependencies and root causes of the problems to enable effective policy formulation. Most of the policies formulated for implementation worsen the situation and create many emergences in the complex systems structure.

Everything in the world is interconnected, and each intervention in the system in which we live has complex effects, feedback and progress over time, resulting in delays. When delayed effects are produced, it creates incompatibility somewhere else within the system, and when this interaction event is ignored, it can lead to chaos such as famine, food insecurity and subsequent riots (Ecopolicy 2013). The application of CLDs and systems archetypes can complement the matrix tools to help policymakers understand the behaviour of the entire complex systems, which will help provide clarity of consistency in policy objectives. As prospective tools, systems archetypes will alert governments to future unintended consequences based on the policies intended to be implemented. Archetypes as a policy tool will help governments address questions such as: 'Why do we keep seeing the same problems recur over time?' This will close the gap of inadequate information in policy and governance. The identification of systems archetypes is useful for gaining insights into the 'nature' of the underlying problem and for offering a basic structure or foundation upon which models/policies can be further developed and implemented. Through the archetypes and the

CLDs, it was identified that better linear solutions do not solve problems, but a better systemic approach leads to the provision of the right management strategies. This approach should help managers and policymakers with better adaptation and mitigation strategies towards sustainable development for agricultural systems in Africa.

This research adopted the approach of 'teaching to transfer' the art of interconnecting thinking with stakeholders during the workshop, and these are also involved in policy revision and formulation in Ghana. These 75 stakeholders were introduced to and educated about the art of interconnected thinking. The Director of Science, Technology and Innovation at the Ministry of Environment, Science, Technology and Innovation (MESTI), the Minister of Agriculture and directors and managers of research institutions were also present. It is believed that these groups will be the facilitators of the art of interconnected thinking in policy formulations. However, the author (who is also a stakeholder of policy formulation) plans to organise a workshop at the governmental level to educate members in the art of interconnected thinking.

Research on strategic management to address Africa's complexity challenges is currently ongoing. Models were validated during a stakeholder workshop in the agricultural industry in Ghana (February 2014). BBN modelling is being used to determine the requirements for the implementation of management strategies and good policies.

4.6 Acknowledgements

Chapter 5: Paper Four: Systemic Management to Africans Agriculture

■ Research Paper

Systemic Management to Address the Challenges Facing the Performance of Agriculture in Africa: Case Study in Ghana†

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Constraints and challenges in the agricultural industry of Ghana limit its productivity. Policy constraints could be a major issue when it comes to agricultural sustainability. Whether policymaking is based on sound principles that take into account the intended and unintended approach consequences led to exploring the use of a fresh approach towards determining effective interventions (policies) through a systems approach. Capacity building using a systems thinking that focuses on the four levels of thinking and using the concepts of an Evolutionary Learning Laboratory during a series of stakeholder workshops in Ghana has shown a remarkable impact on the ability of the agricultural industry to evolve, improve and raise its efficacy. Results from Bayesian belief network (BBN) models indicated that the implementation of systemically determined interventions, policies and strategies could result in chances of 'agricultural productivity' being 'good' as high as 92.2% from 57.5%, while the chances of reducing poverty levels from 44.9% to 10.0% are plausible. These would also lead to a significant increase in the yield and profit of the farmers. These BBNs are used for scenario testing to determine the potential outcomes of different systemic interventions by observing what would happen to the system as a whole when a particular intervention/strategy or combination of interventions/strategies are implemented: that is, before any time or money is invested in actual implementation. This approach provides more clarity on dealing with complex sustainability challenges and should gradually replace the reductionist approach (e.g. short-term quick fixes and treating the symptoms) in dealing with challenges and developing policies. Copyright © 2015 John Wiley & Sons, Ltd.

Keywords: system dynamics; sustainable agriculture; Africa; complexity; decision-making

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Principal Author

Name of Principal Author (Candidate)	Kwamina Ewur Banson
Contribution to the Paper	The conception and design of the manuscript, establishing methodology, conducting workshops in the study area for data collection and models validation in Ghana. Compiling, analysing and interpreting data, working on the development of the first draft manuscript and the writing and submission of the final version.
Overall percentage (%)	85%
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature	Date 16/06/2016

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

  i. the candidate's stated contribution to the publication is accurate (as detailed above);

  ii. permission is granted for the candidate to include the publication in the thesis; and

  iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Nam C. Nguyen (Principal Supervisor)
Contribution to the Paper	Supervising and assisting with the establishment of methodology, planning of the survey, discussions, supervising development of first draft, editing and co-authoring the manuscript.
Signature	Date 27/06/2016

Name of Co-Author	Ockie J. H. Bosch (Co-Supervisor)
Contribution to the Paper	Supervising and assisting with the establishing of methodology, editing and co-authoring the manuscript.
Signature	Date 28/06/2016

Please cut and paste additional co-author panels here as required.

Introduction

5.1.1 Challenges in the Agricultural Domain

Constraints and challenges that impede growth, acceleration and rapid changes in the agricultural system limit the productivity of the sector as a whole (Banson & Danso 2013; Banson, Amoatey & Cobbinah 2004; Gerssen-Gondelach, Wicke & Faaij 2015; Meadows, Meadows & Randers 2004). Poor agricultural policies have presented a major challenge to agricultural sustainability and agricultural development by impeding improved livelihoods and a sustainable environment (Godfray et al. 2010; Reardon & Vosti 1992). Many people in Africa are living in poverty and, as a result, they continue to use natural resources in an unsustainable manner that continues to degrade natural ecosystems (Collier 2007; King 2008).

Agriculture remains a mainstay of the Ghanaian economy, accounting for 40% of the GDP and providing about 70% of formal employment (Chisenga, Entsua-Mensah & Sam 2007; Khor & Hormeku 2006). The importance of agriculture is even greater than these figures suggest, because other sectors of the economy are also linked to agriculture (e.g., processing and the transport and trade of agricultural products and materials) (Khor & Hormeku 2006). The agriculture sector (and especially the subsectors that produce food) is therefore critical in the provision of income and enhancement of livelihoods. Developments within this sector are important in terms of attaining Millennium Development Goals such as the elimination of poverty, achieving growth and food security. According to the Ghana Statistical Service (2013), there has been 23% growth in agricultural GDP over the past seven years, but concerns remain regarding the sustainability of this improvement. The increase in agricultural production during this period at an average rate of 5.5% is likely due to an increase in land under cultivation rather than an increase in productivity (Ghana Business News 2009; International Food Policy Research Institute 2007).

The agricultural sector has undergone significant economic, social and political changes since democratisation in 1957, and it is increasingly facing challenges, especially in the area of food security. The combination of liberalisation and reforms of the 1970s, which were caused by the economic transformation, also exposed the agricultural sector to the adverse effects of globalisation (Banson, Danso & Yaro 2011; Chitiga, Kandiero & Ngwenya 2008; Khor & Hormeku 2006). The marginalisation of farmers—especially smallholders—is further worsened by their inability to handle the cost and administrative burdens of compliance with global standards. Large importers in the EU and US play a decisive role in structuring the production and marketing of primary products exported from Ghana. The requirements they specify for innovation (e.g., new product development, delivery, food safety and quality systems) determine what types of producers and exporters are able to compete in the export

market and maintain access to the agribusiness chain (Banson 2014; Gereffi, Humphrey & Sturgeon 2005). These place smallholder producers in a marginalised position in the export sector.

Agricultural policy plays a central role in promoting growth and poverty reduction in the Ghanaian economy. The past 10 years have produced numerous and encouraging modernisation efforts to improve the agricultural sector in Ghana. Numerous traditional and reductionist approaches through collaborations between research institutions, universities, end users and other development partners have attempted to address many of the constraints facing the agricultural industry; however, agricultural production and productivity continue to decline (Practical Action & PELUM 2005; Banson, Nguyen & Bosch 2014; Davis et al. 2012; Kopainsky et al. 2012; Traoré 2009). According to Omamo (2003) and Banson, Nguyen and Bosch (2014), most agricultural policy research does not benefit agriculture and the overall economy of African communities, notably Ghana. In recent years, a focus on agriculture has been evident in policy and development agendas across the African continent. However, little knowledge has been generated on the interlinkages of research and development, agricultural production, and markets, as well as the potential for developing interlinkages further (Annan 2013). Progress has been slow or negative because of the industry's multidimensional, complex and dynamic makeup, which makes it difficult to solve problems in isolation (Nguyen, Bosch, Ison et al. 2014). These issues and challenges cannot be addressed and solved in isolation and along single dimensions, as in the past. According to Bell and Morse (2005), the traditional and linear approach to sustainable development is one of the major impediments to sustainable development.

5.1.1.1 Need for a New Approach—from Reductionism to Systems Thinking

Agricultural sustainability requires a fresh approach to determining interventions (e.g., policymaking and enforcement) and capacity-building to create a new, more holistic way of thinking in order to evolve, improve and raise the efficacy of the agricultural industry (Banson 2015; Department of Primary Industries 2014; Okoth-Ogendo et al. 2002; Prakash 2000; Vemuri et al. 2009). The systems thinking approach is often seen by critics as being too fundamental and symbolising a technocratic view to business problems, and its dependency on models and lack of actual solutions threaten its legitimacy in management education (Kim 2012b). Nevertheless, Nguyen, Bosch, Ison et al. (2014) and Sherwood (2002) have highlighted and addressed problems in integrated approaches with systems thinking models that clearly demonstrate how to translate hitherto difficult ideas into highly useful management tools for change. This has led to enlightenment among stakeholders that traditional approaches to dealing with today's complex agricultural challenges are mainly

quick fixes that treat the symptoms. Further, the reductionist approach does not take into consideration the system as a whole, and it has resulted in unintended consequences (Banson, Nguyen & Bosch 2014; Bosch et al. 2007; Forrester 2007; Gharajedaghi 2005; Maani 2010; Mai et al. 2012; Nguyen & Bosch 2013).

One problem with the reductionist approach (analysis) to research is that the results or outcomes are often far from real-life settings to the extent that, when adopted by policymakers, entrepreneurs or the public, they often cause unintended consequences that require expensive mitigation (Bevilacqua & Petroni 2002; Bosch & Nguyen 2011; Pasmore & Friedlander 1982; Petticrew & Roberts 2008; Stone, Maxwell & Keating 2001). The world is seeking a new paradigm to deal with the agricultural challenges and problems that have been generated by unintended consequences posed by previous reductionist approaches to solutions in practice (Banson, Nguyen & Bosch 2014; Bawden 1991; Murdoch 2000; Pretty 2008; Van Huylenbroeck & Durand 2003; Wallerstein 2011).

The challenges posed in the African agricultural system are no exception. Innovative practitioners, scientists and indigenous land managers are adapting, designing and managing diverse types of policies/business plans to generate positive benefits for production, biodiversity and local people (Maani & Cavana 2007; Nguyen, Bosch & Maani 2011; Nguyen, Bosch & Nguyen 2014; Scherr & McNeely 2008). There have been a number of interventions to overcome the challenges facing agriculture in many African countries (including Ghana), but with little success (Aryeetey, Harrigan & Nissanke 2000; Banson, Nguyen & Bosch 2014; Kherallah et al. 2000; Krueger, Schiff & Valdés 1988; Nguyen, Bosch & Nguyen 2014; Pretty 2008; Tripp 1993).

There has been a considerable upsurge in the development of policy and implementation actions during the past eight decades, which may have considerable sustainability implications for agricultural productivity in Ghana. The policy tools used include the opportunities and risks matrix, compatibility matrix, priority matrix and the compound matrix (MOFA 2007). However, these tools analyse the above policies based on the symptoms of the problems rather than providing complex maps that could reveal the interconnectedness, dependencies and root causes of the problems. Without an understanding of the interconnectedness between all of the system's components, effective policy formulation and implementation remain problematic, as most policies demonstrate 'organisational myopia' in which a fix 'now' gives rise to much bigger problems to be fixed 'later' (Sherwood 2002).

It is clear from this discussion that the challenges to effective policy formulation are complex. To help address these challenges, there is a need to equip policymakers, researchers and all relevant stakeholders with a new way of 'thinking' beyond the traditional 'linear' approach of

solving problems to a holistic systems approach that focuses on the root causes and interconnectedness between various components of the agricultural sector.

Systems thinking principles lend themselves to effective decision making and business planning (Jackson 1995; McIntyre-Mills 2008; Rouwette, Größler & Vennix 2004). Understanding these principles and integrating them into planning are critical to understanding and adapting to the dynamic nature of organisational, local and global systems. According to Porter, Goold and Luchs (1989), every business plan or policy document must pass reality, competitive and value tests. However, without a systemic test, it would fail to realise the embedded business systems and would lead to business or policy failure in the long run. In the context of this paper, a systemic test is defined as the objective evaluation of the effects that new businesses will have on the holistic business system, and the identification of its influences on the entire system. This will provide a clearer picture of how to regulate its strengths and weaknesses among the components of the system.

For many practitioners and policymakers, 'systems thinking' is a new concept for sustainable management, and its application to agricultural sustainability management in Africa has not received much attention. The theory of this approach uses thoughtful, realistic examples to develop an understanding by policymakers and managers to not only realise when a more systemic solution is possible, but also how to uncover the most effective solution.

This paper reports on the employment of a systems thinking approach and the use of various systems tools to address the sustainability constraints and challenges affecting the performance of the agricultural sector in Ghana. It introduces possible new strategies or solutions that need to be designed to overcome these challenges in the agricultural sector of Africa, including Ghana. It is a direct follow-up to the publications of Banson et al. (2015), who identify the pressing issues facing stakeholders and the performance of the agricultural sector in Africa, including Ghana. In addition, Banson, Nguyen and Bosch (2014) use system archetypes to identify stakeholders' opinions concerning how the agricultural system works, the barriers to success and the system drivers in Africa, including Ghana.

5.2 Methodologies for Managing the Complex Challenges of Agriculture Systems

5.2.1 Why Systems Thinking Approach?

Systems thinking is a scientific approach that involves the art of interconnected thinking and a set of tools to deal with complexity, ambiguity and the integration of mental models into systems structures. It suggests moving away from the information stage (i.e., seeing single elements and events) towards revelation knowledge (i.e., seeing the processes in which they

interrelate). The systems thinking approach provides insights into the structure and behavioural patterns of organisations. These help to reveal the root causes of challenges, plan the future, reduce risk, anticipate delays and prevent significant unintended consequences (Banson et al. 2015). Systems thinking gives rise to a new art of thinking required in business, management and finance, as well as the technical aspects of managing economic development and challenges facing the performance of agriculture in Africa. Agricultural stakeholders and organisations are often counselled to develop strategic alliances that can address changing demand and sustained environments while improving the quality of life (Brester & Penn 1999; Cornelissen & Durand 2014). A systemic approach to strategic agricultural management implies that the natural and human environments make up a holistic system comprising individual components that are interrelated and affect each other, therefore affecting the whole. This helps to build a competitive advantage over traditional approaches, which can lead to long-term above-average returns for relevant stakeholders in the system. By using a systemic approach, one can test the possible outcomes of different systemic interventions by observing what would happen to the system as a whole when a particular strategy or combinations of strategies is implemented—that is, before any time or money is invested in implementation. For Africa and the rest of the world to leave behind complex challenges that result in famine, pestilence, war and terrorism, we need to move past the information stage to revelation knowledge.

5.2.2 Systems Thinking Approach

The systems thinking approach is a method of making sense of a system of components and how they relate to each other (Jackson 2006; Sherwood 2002). It is a method of mapping out a large body of uncertainty and identifying leverage points where a small effect can create a bigger change in the whole systems, thus answering the call for solutions. Systems thinking takes on complex, dynamic systems and demonstrates how they behave over time.

5.2.2.1 Causal Loop Diagrams

CLDs consist of variables that are connected by causal arrows with polarities, such as 'positive' '+' and 'negative' '-' signs and delays '||', to describe causal linkages (Schaffernicht 2010; Senge 2006; Sherwood 2002). Feedback loops describe the circles of cause and effect that take on a life of their own. For example, Figure 5.1 illustrates the feedback loops of policies or business plans that fail to comply with a systemic test.
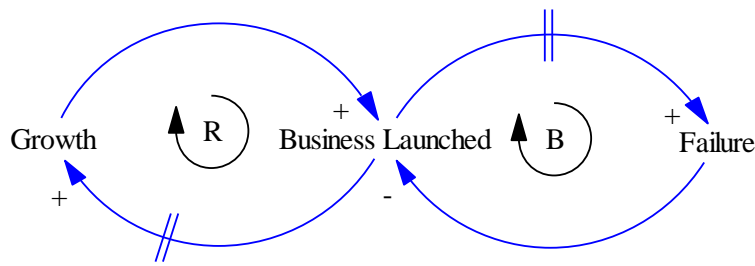
Figure 5.1: New business development model

The arrows in Figure 5.1 form feedback loops. Feedback loops in a CLD indicate feedback in the system that is being represented. This indicates that a given change sets off changes that cascade through other factors to either amplify ('reinforce') or push back against ('balance') the original change. Figure 5.1 indicates that when more businesses are launched, there is more business growth, which leads to the launch of more businesses. This is called a reinforcing feedback loop; it is marked with an 'R' because more growth today leads to more investment in launching new businesses in the future. Growth reinforces growth. Similarly, less growth would lead to the launch of fewer businesses, which would lead to less business growth in the future. Thus, the reinforcing process also works in the negative direction. If this is the only feedback loop in the business-launching system and businesses do not fail, there would be exponential growth in the number of businesses launched.

A different type of feedback loop appears when we examine business failure. Perhaps more business failures today lead to fewer business failures in the future. This is because more business failures today will result in a decrease in the number of businesses launching. Thus, fewer businesses will be available to fail later. These types of loops are called balancing feedback loops ('B'), as more leads to less and less leads to more. The original change is balanced by a change in the negative direction. The arrows have a delay mark ('‖') on the causal arrows between business launch and growth and between business launch and failure, indicating that it will take time before the effect starts to play out (Senge 2006; Sherwood 2002). It takes time for businesses to grow and reach maturity, which is why there is a delay between business launch and growth. Connections can be conceptual, including cause and effect (A causes B), time sequencing (B follows A), contingency (whether B happens depends on A happening). Influence (A influences B) is always one of the connections between the components of a system (Armson 2011). This is a manifestation of the observation that adding, removing or changing a component changes the whole system.

CLDs are diagrams that show the current relationships among the system elements under examination using tools such as Vensim software (Ventana Systems UK 2002). The development of CLDs provides all relevant stakeholders with a 'big' picture of the systems

within which they are operating. CLDs also display the interactions between the different components of the system, as well as their effect on the system.

5.2.2.2 Evolutionary Learning Laboratory

The ELLab offers a methodology for creating informal learning spaces or platforms for managing complex issues (Bosch et al. 2013). It aims to introduce systems thinking for researchers, research managers, policymakers and other decision makers to develop a shared understanding of complex issues and create innovative and sustainable solutions using systems approaches. The research processes include generic skills in problem solving, team participation and team learning. It consists of a seven-step process and methodology for integrated cross-sectoral decision making, planning and collaboration in dealing with complex multi-stakeholder problems.

5.2.2.2.1 Research Process

The methodology used in this study includes a literature review and industry (stakeholder) surveys through the use of the ELLab framework shown in Figure 5.2.
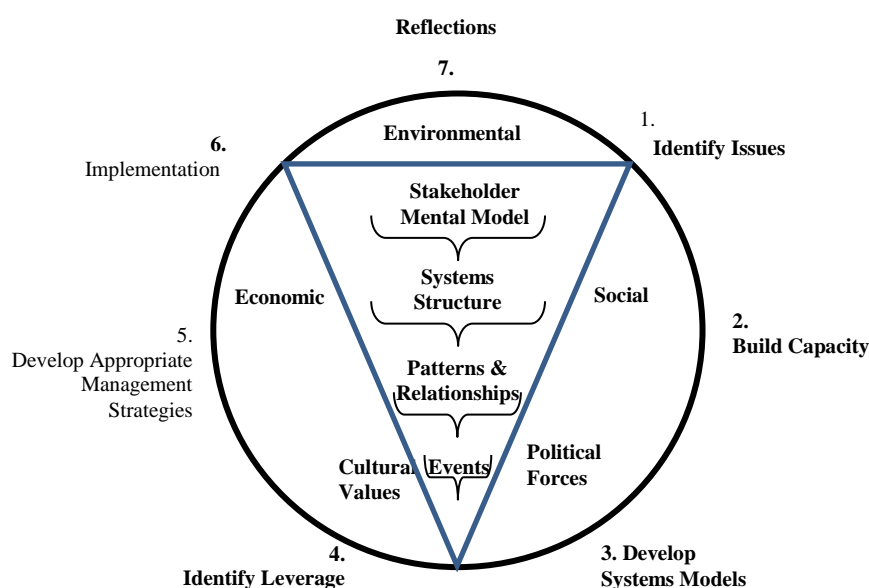
Figure 5.2: Steps in an evolutional learning laboratory for managing complex challenges (adapted from Bosch et al. 2013).

The combination of data obtained from Ghana, interviews and the literature review through the use of the four levels of thinking model embedded in the ELLab provided an overview of the current structure and effect of management strategies on the agriculture system riddled with feedback loops. Data collection started by gathering the mental models of all stakeholders involved in the agriculture industry in Ghana during a workshop in 2011 to revise the FASDEP II. A series of follow-up workshops and interviews were conducted in 2013 and 2014 with relevant stakeholders in Ghana to analyse the system barriers and drivers

to agricultural sustainability. The BBN and other models were validated by organising another series of workshops in 2014 for further stakeholder group consultations (with the same stakeholders that were involved in the first workshops in 2013) to confirm and validate all of the models.

Figure 5.2 starts at the 'fourth level of thinking', which is the initial step that involves a series of workshops with stakeholders (e.g., agricultural scientists and extension officers, farmers, exporters, input suppliers) to obtain their mental model through engagement and exploratory questions. This was done through stakeholder focus group discussions to deliberate on the constraints and challenges affecting their business, as well as the effects of the challenges, and to suggest potential new strategies or solutions to overcome these challenges.

This was followed by step two, which was the 'third level of thinking' through follow-up capacity-building sessions in several workshops, during which the participants and researchers learned how to integrate the various mental models into a systems structure using the Vensim software program (Ventana Systems UK 2002). It is important to note that capacity-building was an integral part of all of the steps of the ELLab process.

Once completed, the participants moved to step three, the 'second level of thinking', by interpreting and exploring the model for patterns and their interconnected components, and to analyse the kind of feedback loops, reinforcing loops and balancing loops that exist. This step was aimed at assisting stakeholders to develop an understanding of their interdependency and their role and responsibility in the entire system.

These processes led to step four, which provided stakeholders with a better understanding of each other's mental models and the development of a shared understanding of the issues under consideration. The interpretation led to the identification of leverage points for systemic intervention. Leverage points are places within the complex agricultural system where a small intervention at a point can generate a large effect.

In step five, the outcomes were used to develop a refined systems model for the identification of systemic interventions. For this, BBN modelling was used to identify the systemic interventions and determine the requirements for the implementation of the systemic management strategies and/or systemically based policies. This was followed by the identification of factors that could affect the expected outcomes, and then the order in which activities should be carried out to ensure cost effectiveness and maximise effect. The process of developing good policies and investment decisions is based on the best knowledge (scientific data and information, experiential knowledge, expert opinions) available at any point in time (Bosch et al. 2013). A BBN is a graphical representation of a probabilistic dependency model in the Bayesian sense (Cain 2001; Krieg 2001). It consists of a set of

interconnected nodes, where each node represents a variable in the dependency model, and the connecting arcs represent the causal relationships between these variables. Each node or variable may take a number of possible states or values (Banson et al. 2015). The belief in, or certainty of, each of these states is determined from the belief in each possible state of every node directly connected to it and its relationship with each node (Krieg 2001). The belief in each state of a node is updated whenever the belief in each state of any directly connected node changes (Cain 2001). The structure of the BBN model and its data were obtained and developed from the literature review and focus group discussions with experts (Banson et al. 2015). The effect of the available evidence on any variable (hypothesis) may be ascertained by marginalising the joint probability of the entire network to obtain the posterior probability of that variable (Krieg 2001). The BBN models were constructed using Netica software (Norsys Software Corp 2014). They are used as a simulation model to test the possible outcomes of different systemic interventions by observing what will happen to the system as a whole when a particular strategy or combination of strategies is implemented; that is, before any time or money is invested in implementation. Thus, data on the farmers' poverty measure were analysed to determine how the adopted interventions would affect their poverty status.

In step six, once the systemic interventions have been identified and an operational plan has been developed, people who are responsible for the different areas of management implement the strategies and/or policies that will create the biggest effect. Targets are determined and monitoring programs are implemented to measure and/or observe the outcomes of the strategies and policies. In many cases, it only requires an adjustment to existing monitoring programs to comply with the targets set within the process (e.g., to include factors to be measured that were used in the construction of the Bayesian management model).

This research adopted the approach of 'teaching to transfer' the art of interconnecting thinking with stakeholders during the workshop, and these were also involved in policy revision and formulation in Ghana. In addition to the stakeholders, the Director of the Science, Technology and Innovation of the MESTI, the Minister of Agriculture, and directors and managers of research institutions were also present. It is believed that these groups will be the facilitators of the art of interconnected thinking in policy formulations. However, the author (who is also a stakeholder of policy formulation) plans to organise several workshops at the governmental level to educate members in the art of interconnected thinking and its relevance to systemic adoptive management.

In step seven, as no systems model can ever be completely 'correct' in a complex and uncertain world, the only way to manage complexity is by regularly reflecting on the outcomes of the actions and decisions that have been taken to determine whether the

interventions are successful and to identify unintended consequences and new barriers that were previously unforeseen.

This study focused on the first five steps of the ELLab, but they form part of the seven-step process, as they will be embedded in the co-learning cycle of the ELLab.

5.2.2.2.2 Measures of Poverty

The estimates of poverty were evaluated to integrate the present status of poverty among respondents in the study area into the BBN models. The head count index indicates the proportion of the sample size that is regarded as poor (Banson et al. 2014; Ravallion & Datt 1996). If the sample size is 'n' and 'q' is the number of poor people, then the head count index may be represented as: Head Count Index (HC) = q/n.

Conversely, the poverty gap index highlights poor people who are below the poverty line. If 'z' is the poverty line and 'y_i' is the income of an individual 'i', the poverty gap is estimated as:

$$Poverty\,Gap\,(PG) = \frac{1}{n}\sum_{i=1}^{n}\frac{\{z - y_i\}}{z}$$

The poverty gap may also be estimated as the product of the income gap and the head count (HC) index ratio as given below:

PG = I x HC

Where I is the income gap and HC is the Head Count Index.

The income gap was estimated as: $\quad I = \frac{z - y_q q}{z}\,and\quad y_q = \frac{1}{q}\sum_{i=1}y_i$

Where 'I' is the average income of the poor and 'y_q', the average income of the poor, was also estimated as:

$$y_q = \frac{1}{q}\sum y_i$$

The squared poverty gap measures the severity of poverty. It gives more weight to the poor and is depicted as:

$$Squared\,Poverty\,Gap\,(PG)^2 = \frac{1}{n}\sum_{i=1}^{n}\frac{\{z - y_i\}^2}{z}$$

The general formula for these three measures, which depend on parameter $\propto$, is given as:

$$P(\propto) = \frac{1}{n}\sum_{i=1}^{q}\frac{\{z - y_i\}^{\propto}}{z}$$

Where $\propto$ takes a value of 0 for the head count index, 1 for the poverty gap index and 2 for the squared poverty gap index.

5.3 Results and Discussion

5.3.1 Key Challenges of the Agriculture Industry of Ghana

According to the information obtained through the workshops, market liberalisation and governmental decentralisation policies have altered Ghana's agricultural systems to dramatically transform the social, political, economic and cultural lives of the stakeholders involved. Ghana's 'agricultural systems' mainly comprise the government (MOFA and research institutions), farmers (producers and exporters) and actors (inputs suppliers), as illustrated in the CLD (see Figure 5.3).

Figure 5.3 illustrates the feedback loops of Ghana's agricultural industry performance by demonstrating the factors influencing system output and sustainability. The arrow links in Figure 5.3 form feedback loops. This indicates that a given change sets off changes that cascade through other factors to either amplify ('reinforce' [R]) or push back against ('balance' [B]) the original change. The colours in Figure 5.3 represent each main stakeholder platform that constitutes the agricultural systems: green for farmers, blue for the MOFA and red for the actors.

These multi-stakeholder platforms engender agricultural development in Ghana; however, the government is yet to increase its budget spending on agricultural development to reach the 10% target of its total budget, as agreed in the Maputo Declaration (METASIP 2010).
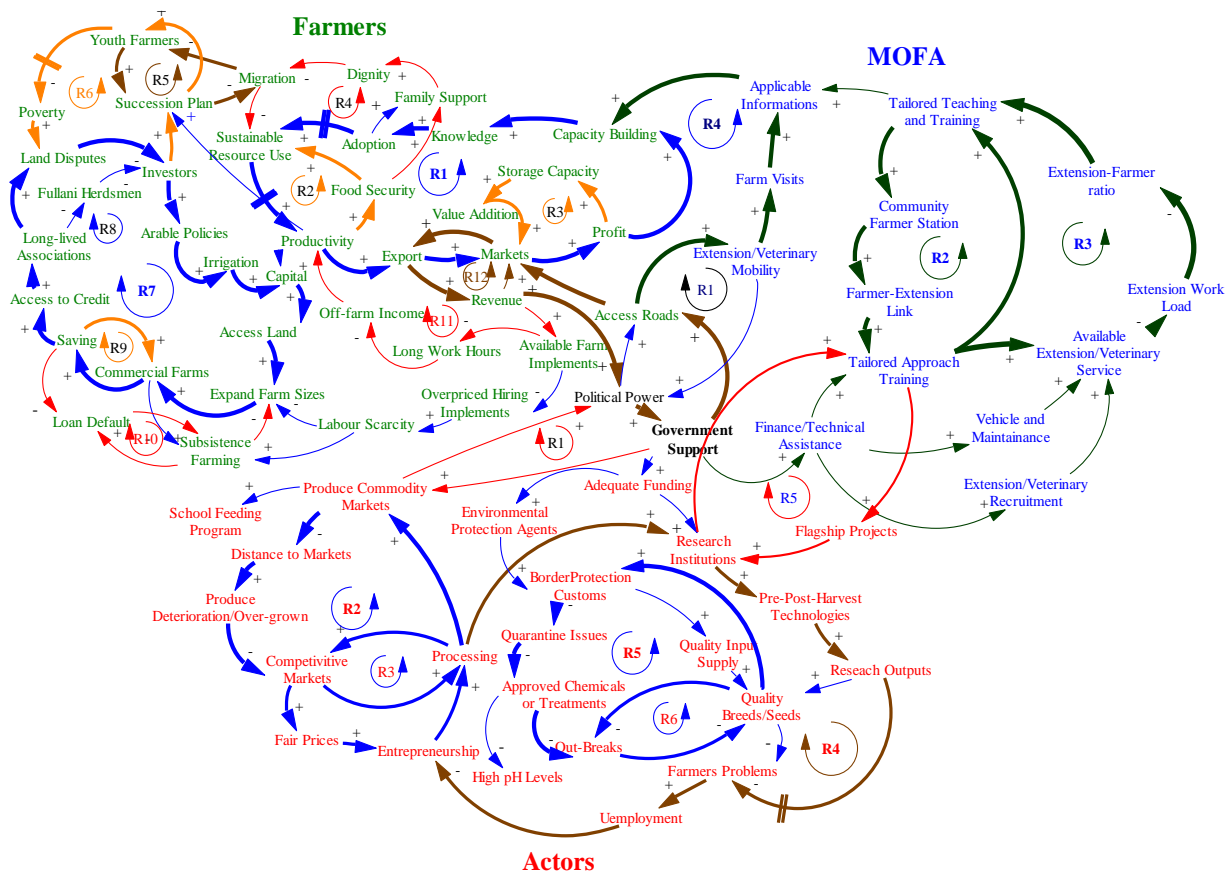
Figure 5.3: CLD of the agricultural industry of Ghana—demonstrating factors influencing system output and sustainability

The identified basic problems of the agriculture sector include reliance on rainfall, low-performing irrigated agriculture, low level of mechanisation in production and processing, high post-harvest losses as a result of poor pre- and post-harvest management, low level and ineffective agricultural finance, poor extension services, inadequate markets and processing facilities, low-performing seeds/breeds, divestment in pasture production for livestock, high cost of poultry feed, poor livestock housing and husbandry management, competition from imports and poor post-production management of livestock products, over-fishing of natural water bodies, undeveloped fish value chain, and inadequate skills in aquaculture.

The CLDs of the main groups are shown in the combined CLD in Figure 5.3. These will be discussed separately in the following sections

5.3.1.1 Ministry of Food and Agriculture

MOFA is the lead agency responsible for the agricultural sector within the context of a coordinated government programme. It is committed to agricultural research and technology development and transfer, and it directs the optimisation of agriculture's role in national growth and development. Agricultural extension is part of the MOFA, with field extension officers at the bottom of the hierarchy and a minister at the top. Agricultural extension officers are a potent and critical force in the agricultural development process. They assist

farmers through training activities to improve farming techniques, increase production efficiency and income, improve their standard of living, and lift the social and educational standards of rural life. Agricultural extension officers also communicate agricultural research findings and recommendations to farmers and give them useful information. Farm visits are the most common form of personal contact between extension agents and farmer, often constituting more than 50% of agents' extension activities (Oakley & Garforth 1985). As they take up so much of the agent's time, it is important to be clear about the purpose of such visits and to plan them carefully. Farm visits can familiarise the extension agent with the farmer and his or her family, enable him or her to give specific advice or information to the farmer, build up the agent's knowledge of the area and the kinds of problems that farmers face, permit him or her to explain a new recommended practice or follow-up and observe results to date, arouse general interest among the farmers and stimulate their involvement in extension activities.

Figure 5.3a: CLD of MOFA

However, these extension agents are faced with challenges beyond their control for the effective performance of the sector. These challenges are illustrated in Table 5.1.

As shown in Figure 5.3a, these challenges have placed more pressure on extension or veterinary agents to deliver tailored teaching and training to farmers. Extension services' information delivery to crop and livestock producers has declined in the past decade. Over the past 6 decades, numerous changes have taken place in the Ghanaian agricultural extension system as a result of structural changes, rapid urbanisation and inadequate resources to provide services to farmers. The government's reluctance to recruit more extension workers affects their presence and therefore the effectiveness of the extension services in the field.

If the government can provide finance in the form of tailored training, vehicles and maintenance, and staff recruitment, extension services will be available, thereby reducing the workload and improving extension–farmer ratios. This will foster tailored training to meet farmers' needs through capacity-building (Department of Primary Industries 2014; Okoth-Ogendo et al. 2002; Prakash 2000; Vemuri et al. 2009). Using a tailored approach means obtaining information, advice and professional support that suits the needs of the targeted farmers.

Table 5.1: Challenges impeding agricultural development by MOFA

Stakeholder	Internal	External
MOFA Extension agents	Lack of mobility (motor bikes/cars) and logistics (field aprons, field note books, vehicles)	No access roads to farmers
	Irregular transport fare to travel and do farm visits and no risk allowance	Farmers' inability to form lasting/viable farmer /cooperative groups
	Lack of demonstration farms	Farmers' rigidity to adopt technology; no one structured stakeholder forum
	No maintenance allowance for already acquired vehicles	Lack of research-extension farmer linkages
	Understaffed agents: extension farmer ration is poor 1: 3,000. Veterinary farmer ratio 1: 5,000	Long distance to farming land as a result of urbanisation; poor services

5.3.1.2 Farmers

A smallholder farming operation is typified by *ad hoc*, uncoordinated individual plantings or rearings where no authorisation is required from the relevant authorities. There is therefore no record of the exact number of farmers cultivating in Ghana. This system has made it difficult to determine the number of extension officers to deploy in a particular region. Farmers' major challenges are included in Table 5.2.

Challenges exist relating to Fulani Herdsmen, who are accused of rape, murder and causing harm to farms and farmers. Another challenge is the fact that in savanna areas, the land is becoming drier, and increasingly irregular and unpredictable rainfall can cause crops to fail, so people are at constant risk of famine. Overgrazing from livestock and high demand for firewood also means that tree cover is reducing. These challenges combine to create an increasingly barren landscape where the soil cannot hold water or nutrients, thereby leading to desertification. Land and property rights are also a critical policy challenge in Ghana. There is no security of farm land, especially in the face of urbanisation.

Table 5.2: Farmers' major challenges impeding agriculture sustainability

Stakeholder	Internal	External
Crop, fish and livestock farmers	Few cultivation skills, knowledge, understanding of markets' requirements for specific crop varieties, standards requirement, specified production volumes and timeliness of delivery	Poor access to credit and finance
	High ph levels in soils,	Pest and diseases
	Overgrazing from livestock and high demand for firewood	Scarcity of hired labour
	Short-lived cooperative associations/farmer groups	Challenges with Fulani-herdsmen
	Theft issues	Unreliable rainfall pattern (climate change),
	Unavailability of farm lands	Lack of access roads to farms and markets
	No extension -farmer links	Poor access to extension/veterinary service, lack of 'farmer station' to seek help
	Rapid deterioration of fresh produce, and dried up water sources	Lack of farm implements and high hiring costs
	Fake and poor breeds/seeds	Unsatisfactory government support, poor policy, challenges with animal housing, quarantine issues

As shown in Figure 5.3b, these challenges negatively affect farmers' productivity, profitability and food security. When farmers in rural areas experience a lack of access to services, opportunities, employment, resources and education, they feel less dignified. For farmers to maintain their dignity, they are forced to put more stress on the land and water, resulting in an increase of soil degradation and salinisation of irrigated areas. When their efforts do not pay off, they (mostly youths) migrate to urban areas and cities, leaving the aged in the farming business. However, this places too much pressure on the cities and causes overcrowding and other social problems, often leading to the growth of slums, unemployment and crime.

The lack of sufficient government support is among the many risks that negatively affect the agricultural production potential in Ghana and many African countries. If the government provides support in the form of access roads from farms to market centres (see Figure 5.3b), it will motivate farmers to be market-oriented producers. Efficient, accessible and equitable markets are essential to transform Ghana's agriculture from *ad hoc* and uncoordinated small-scale production into a planned and market-oriented system, and to reduce poverty and food insecurity.
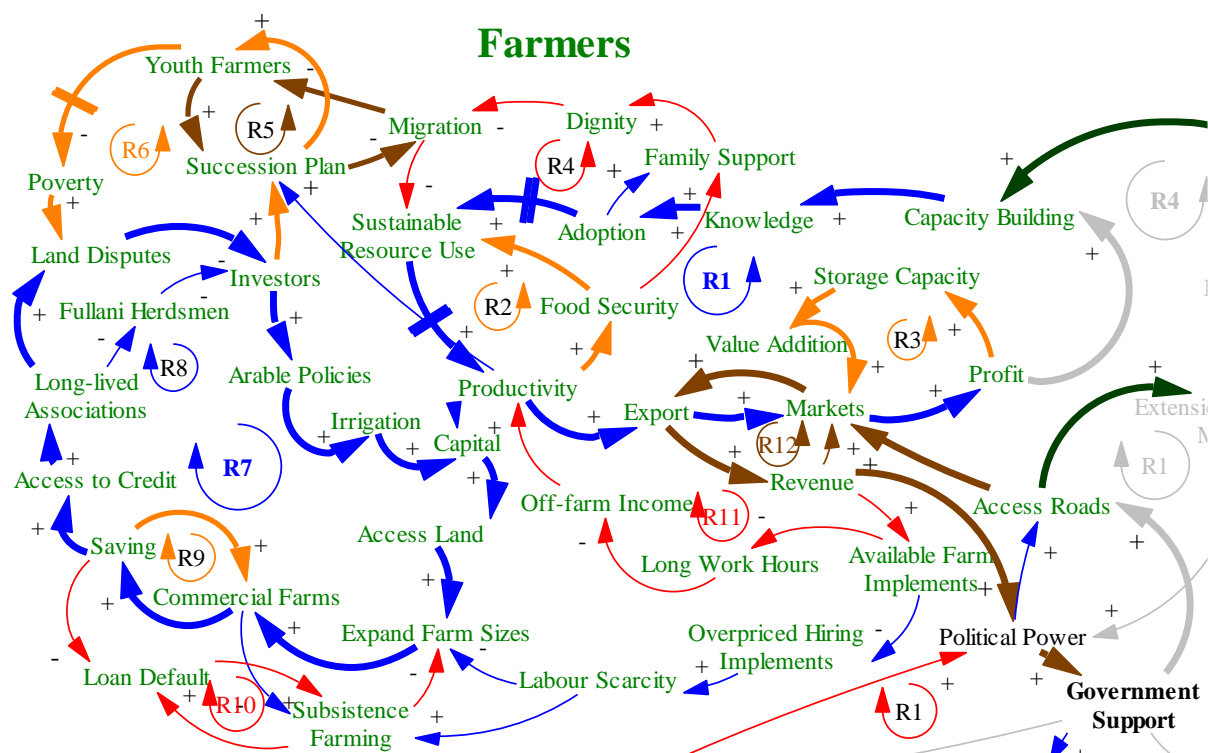
Figure 5.3b: CLD of farmers

This will increase their profit margins and enable them to engage in capacity-building programs to improve their knowledge and skills (Department of Primary Industries 2014; Okoth-Ogendo et al. 2002; Prakash 2000; Vemuri et al. 2009). Knowledge is power. With knowledge, farmers will be greater risk-takers through technology adoption, which will improve their resource use and dignity, as knowledge is the key determinant of adoption. Sustainable resource use will improve productivity and increase yields for export volumes, thereby creating/expanding markets. This will generate revenue for the government and increase its political power and chances of re-election.

5.3.1.2.1 Poverty Gap and Squared Poverty Gap

The estimates of poverty were evaluated to assess the present status, depth and severity of poverty among respondents in the study area. The poverty line (P1) of US$38/month was the official poverty line inflated for 2008. The common international poverty line has been around $1 per day in the past. In 2008, the World Bank released a revised figure of $1.25 at

2005 purchasing power parity (Chen & Ravallion 2008). The average monthly incomes (P2) of 51 farmers were recorded in this study. The poverty estimates were computed on the basis of farm gate income. Farmers' incomes ranged from US$30.58 to US$52.89 per month, and this varied with the farming season. Twenty-six per cent of the farmers live below the poverty line, and these farmers depend only on rainfall. The overall poverty gap among farmers who only depend on rainfall was 0.08, indicating that poor households needed an additional 8% of their present income to attain a minimum basket of basic needs. The severity of the poverty index among respondents involved in the workshop was 3.3%, and higher among those with irrigated lands. In the latter case, the poverty index was 4.4%, while farmers who were not irrigating had an index of 1%. The poverty severity index is basically a poverty gap that measures the gap between 'Poverty line (P1)' and 'the average income of poor people (P2)'. The greater the gap, the deeper their poverty.

5.3.1.3 Actors

Agricultural actors include input producers and suppliers such as agrochemical companies, traders and processors, waste management/aquaculture companies, research institutes, seed producers and bee keepers. Constraints faced by various agricultural actors are shown in Table 5.3.

Table 5.3: Constraints faced by various agricultural actors

Stakeholder	Internal	External
Actors	Complex certification process under the environmental protection agency and the Ghana standards boards	Low adoption of good agricultural practices (gap) by farmers
	Low patronisation of improve seeds by farmers	Labour layoff
	Lacking research facilities	Inadequate extension service
	Inadequate marketplaces	Inadequate supply of fish seed
	Agrochemicals killing bees and contaminating honey	Lack of credit facility and logistics
	No security (theft)	Bushfires caused by hunters
	Deforestation	Poor access to equipment
		Poor mobility due to poor roads

These challenges suffocate young businesses and can lead to their collapse, or they can delay the thriving of existing businesses.

In designing and addressing interventions, it is critical for the government to provide adequate funds for research and development to create an enabling environment for entrepreneurship and business development. This will promote research to address flagship challenges facing stakeholders, with tailored research outputs for end users. As a result, many challenges will be overcome to create successfully shared value, which involves creating economic value in a

way that also creates value for society by addressing its needs and challenges (Porter & Kramer 2011). Creating a successful shared value is an act of entrepreneurship and interconnected thinking. The proliferation of processing companies will turn *ad hoc* marketing or a supply of raw material into a supply of final products that has undergone chains of activities that create and build value at every step (Beamon 1999)—that is, to adjust supply to demand in a new market, thereby leading to more research and commercialisation, as shown in Figure 5.3c.
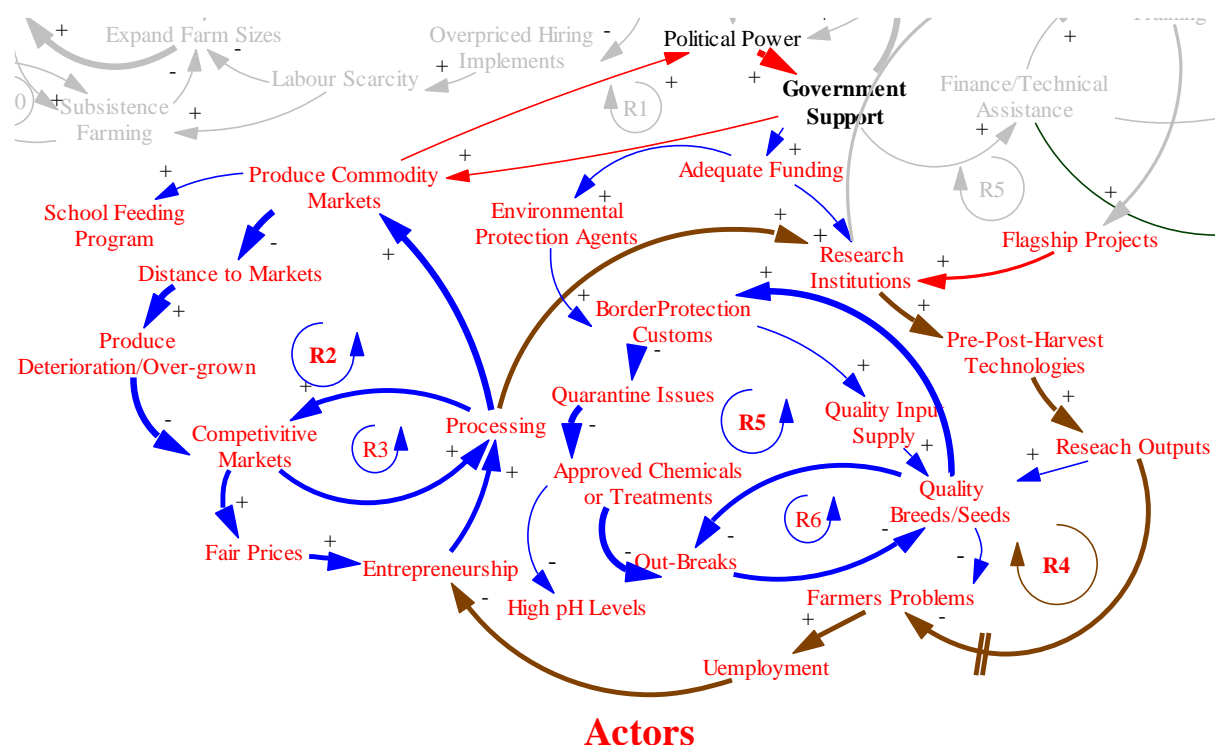
Actors

Figure 5.3c: CLD of actors

5.3.2 Bayesian Belief Network Modelling

BBNs are graphical models that use Bayesian probabilities to model the dependencies within the knowledge domain. They are used to determine or infer the posterior marginal probability distributions for the variables of interest given the observed information (Krieg 2001). Stakeholders contributed their expertise based on accumulated knowledge and experience in addition to other available sources of information for the development of the BBN models. Stakeholders identified increasing agricultural productivity, access to extension/veterinary services and enabling an environment for entrepreneurship as their main leverage points. Unavoidably and admissibly, the use of public money is heavily scrutinised, and investments and interventions must demonstrate value for money both before and after their inception. The construction of BBN models provides a holistic approach to decision support and encourages

stakeholders' involvement for a more rigorous and comprehensive formulation of management strategies (Cain 2001). The causal relationships in BBNs enable the correlation between variables to be modelled and predictions to be made, even when direct evidence or observations are unavailable (Krieg 2001). BBNs also blend prior knowledge with the data through the use of both prior probabilities and conditional probabilities. These characteristics of BBNs give them an advantage over classical probability techniques (Cain 2001; Krieg 2001). BBNs also explicitly represent uncertainty in a way that can be clearly understood. However, building a fully functional BBN recognises stakeholders' perspectives through consultation, data collection and collation.

Having constructed the conceptual BBN framework, the BBNs were turned into fully functioning BBN models that can be used to help make decisions. This was done by populating the CPTs using the best and most appropriate data and experiential knowledge from stakeholders. The data in the CPTs describe how a node changes in response to changes in its parents. Questions were logically framed to capture data for each node regarding how people react to changes in the environment. For example, 'If forest cover is good and rainfall is good, what is the chance that river flow will be good, acceptable or bad?' Each question (for each row of the CPT) suggested the data that needed to be collected to complete the CPT (Cain 2001). In other cases, data were obtained by direct measurement (e.g., poverty measurement, population measured by census, income measured by accounting). Information from process-based models such as from the FAO, the Human Development Index of the UNDP and academic 'expert' opinions based on theoretical calculations or best judgements were also considered. Finally, the interpolation factor—that is, whether an effect will be positive or negative—was used. All data obtained were checked for validity with FAO and UNDP data and other publications. Further, another series of workshops was organised in 2014 for further stakeholder group consultations to confirm and validate the models. The BBN models (see Figures 5.4a, 5.5a and 5.6a) were used as a simulation to test the possible outcomes of different systemic interventions by observing what would happen to the system as a whole when a particular strategy or combination of strategies was implemented. As the BBN is a network, the effect of evidence is transmitted throughout the network by allowing each variable to continually update its state by comparing the state of its neighbours against local constraints with the relationships expressed by the CPTs. If the local constraints are satisfied, no activity takes place; otherwise, action is taken to correct the constraint violation and messages are sent to the immediate neighbours of that variable (Krieg 2001).

The BBN models were then used to identify the management interventions that were considered the most likely decisions to achieve the objectives.

5.3.2.1 Investment Decision Making

The overall BBN models can be used as scenario-testing mechanisms in the investment decision-making process. The BBN models assist decision makers and managers to test the possible outcomes of different systemic interventions by observing what would happen to the system as a whole when a particular strategy or combination of strategies was implemented— that is, before any time or money was invested in implementation.

The primary input to the decision-making process was the scope description for one or more management objectives that satisfied the systemic intervention requirements (as shown in the figures below). The output of the decision-making process simply reflected the selected leverage points, interventions and probabilities upon which the investment decisions were made. This output information was the basis of the development and implementation process, as well as for systems performance measurement and assessment. The selected leverage points—increasing access to extension/veterinary service, increasing agricultural productivity, and creating an enabling environment for entrepreneurship—were the dominant objectives for maximising wealth creation in the system as a whole. The system interventions, including planning and investment decision making, were not limited to giving priority to interventions that will yield the greatest effect.

5.3.2.1.1 Bayesian Belief Network Modelling for Increasing Farmers' Access to Extension/Veterinary Service

According to the MOFA (see Figure 5.3a), the most difficult challenge is how to make extension services available to farmers in the face of a 1:3000 extension farmer ratio. It is also evident from the discussion above that improving farmers' access to extension services is one of the key leverage points for overcoming the challenges in the agricultural industry. Subsequently, several BBN models (see Figures 5.4a–d) were developed to determine the interventions for improving farmers' accessibility to extension services.
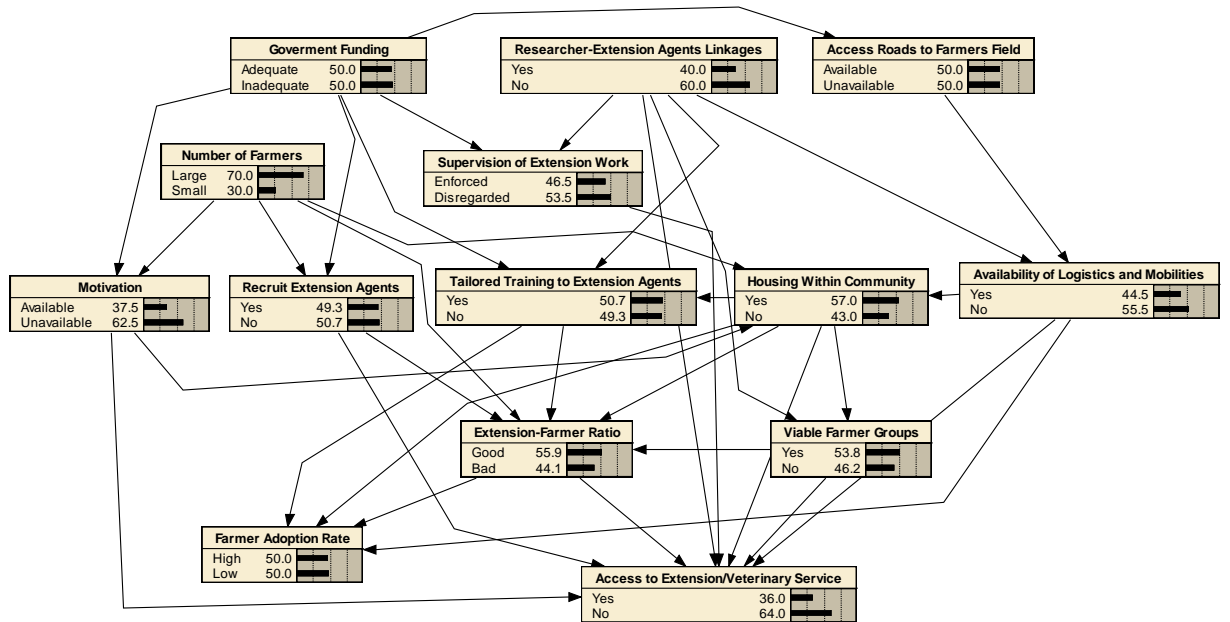
Figure 5.4a: BBN modelling for increasing access to extension/veterinary service

(Current situation)
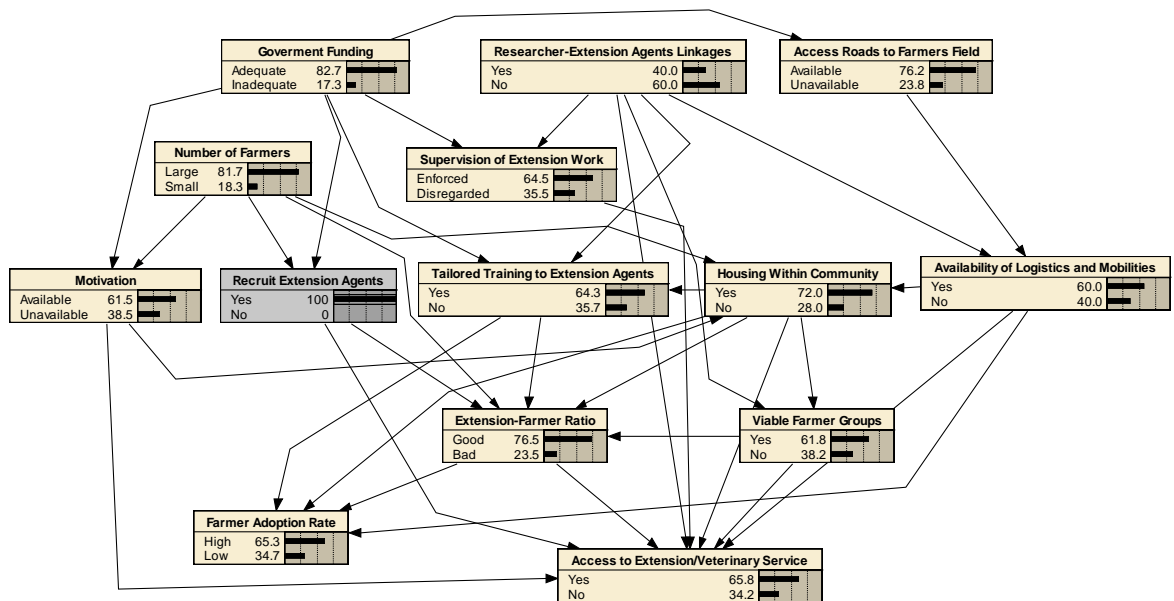
Figure 5.4b: BBN modelling for increasing access to extension/veterinary service

(With intervention: recruit extension agents)

Access to extension/veterinary service	Extension/veterinary service is essentially the means by which new knowledge and ideas are introduced into farming communities in order to bring about change and improve the lives of farmers and their families. Extension, therefore, is of critical importance. Without it, farmers would lack access to the support and services required to improve their agriculture and other productive activities.
Viable farmer groups	As well as knowledge, information and technical advice, farmers also need some form of organisation or group, both to represent their interests and to give them a means for taking collective action. The viable farmer group offers the possibility of greater extension coverage, and is therefore more cost-effective. Using the group method, the extension worker can reach more farmers and in this way and make contact with many more farmers who have had no previous contact with extension activities.
Farmer adoption rate	Not all farmers will accept a new idea at the same time. In any farming community, the readiness to accept new ideas and put them into practice varies from farmer to farmer depending on each farmer's previous experience with new ideas, the personality of the farmer and the amount of land and other resources available. If the farmers are convinced by the innovation, they accept the idea fully and it becomes part of their customary way of farming.
Extension farmer ratio	This is the number of farmers per extension agent. Individual or face-to-face methods are probably the most universally used extension methods in developing countries. The extension agent meets the farmer at home or on the farm and discusses issues of mutual interest, giving the farmer both information and advice.
Motivation	The extension agents often lack the will or the motivation to try to reach out to farmers to help improve their circumstances. The extension agent can offer his support through motivation.
Recruit extension agents	Extension recruitments or employments are mostly done by the MOFA to help farmers in rural regions and to support other extension agents already in field.
Tailored training to extension agent	Tailored training provides extension agents with information, advice and professional support needs that suit the needs of the targeted farmers. Receiving tailored training regularly and linkages with researchers to improve their skills needed to teach and transfer knowledge to farmers.
Housing within community	These are good housing provided to extension agents as a way of motivation within the farming community which reduce their cost of transportation and risk.
Availability of logistics and mobility	The main problem as far as logistics are concerned is mobility of extension agents to the various locations where they have to render their services to the farming communities on a daily basis. Where vehicles and motor cycles are available, they are few and as a result, leave a large number of extension agents without means of transport.
Supervision of extension work	The immediate heads of extension agents lack proper supervision of the field level extension agents because they are not adequately encouraged with vehicles for their mobility through the areas of operation to oversee the work of the field officers at intervals.
Number of farmers	These are the number of market-oriented smallholder farmers within the farming communities.
Government funding	Minimum amount of budget allocated to agricultural development.
Researcher-extension agents linkages	For research findings/innovations to be more accessible and applicable, they need to be available to the farming communities that need them. Linkages between research institutions and extension agents made transfer of these innovations possible. The missing linkages between research and extension organisations need to be strengthened.
Access roads to farmers' field	These are roads linking farmers' farms to the main access roads to enable them to have access to vehicles and participate in market activities.

The BBN model (see Figure 5.4a) shows that the current probability of farmers accessing extension services is poor (36%), with the current chance of farmers' adoption rate as positive or negative. As shown in Figure 5.4a, current farmers' chances of forming lasting farmer or cooperative groups are 53.8%. The probability of the current condition of the extension–farmer ratio is 59.9%, with only 37.5% likelihood that the extension staff members are motivated.

The BBN model (see Figure 5.4a) was used as a decision tool to test the possible outcomes of different systemic interventions by observing what will happen to the system as a whole when a particular strategy or combination of strategies is implemented. They include recruiting extension staff, government improving logistics and mobility of staff, ensuring research extension–farmer linkages, and providing access roads. Figures 5.4b–d show increased levels of access to extension/veterinary services, with spiral positive effects on other components of the systems.

The chances of recruiting or employing new agricultural extension and veterinary officers will increase access to extension services from 36% to 65.8% (see Figure 5.4b). Deprived access to extension services has led to poor agronomic practices, rudimentary post-harvest management, inefficient use of inputs, overuse of pesticides, low adaptive capacity for research and technology use, and other information that could help to increase productivity.

According to the MOFA, graduates from the various agricultural colleges who assist them are not recruited after their 'National Service', thereby leaving a gap until the next service personnel are engaged. The Ghana 'National Service Scheme' was established in 1973 with the mandate to mobilise and deploy Ghanaian citizens of 18 years and above—especially newly qualified university graduates—on national priority development programmes that contribute to improving the quality of life of ordinary Ghanaians for one-year mandatory national service. However, these service personnel are also not committed to working. They mostly spend their time looking for job placements before their 'National Service' is over, as the MOFA is not ready to employ any of them afterwards. Further, politicians have a vested interest in recruiting political supporters, who are mostly not qualified as extension agents, instead of these service personnel. Farmers also complained that they would normally have to provide additional monies to motivate extension agents before they make visits to their farms.

The probability that staff will become more motivated changes from 37.5% to 61.5% as workload decreases through staff recruitment (see Figure 5.4b). According to the MOFA participants who were involved in the workshops, motivation depends on the incentives they value and believe to be attainable with increased performance, and it is high when staff workload is reduced. These incentives include having access to good housing within the

farming community, providing transportation and risk allowances, receiving tailored training regularly and linkages with researchers to improve their skills needed to teach and transfer knowledge to farmers. The probability that the condition of extension-farmer ratio will improve changed from 59.9% to 76.5% and the chances of adoption from 50% to 65.3%, thus motivating farmers more to form viable farmer groups (see Figure 5.4b).

The management decision to improve logistics is a priority according to the BNN model. The results reveal that the organisational factors that affect the performance of extension/veterinary officers are mobility and logistics, which negatively affect job design and administration. With available logistics and mobility and the recruitment of more extension officers, the probability that extension services will be accessible to farmers will improve from 36% to 80% (see Figure 5.4c).
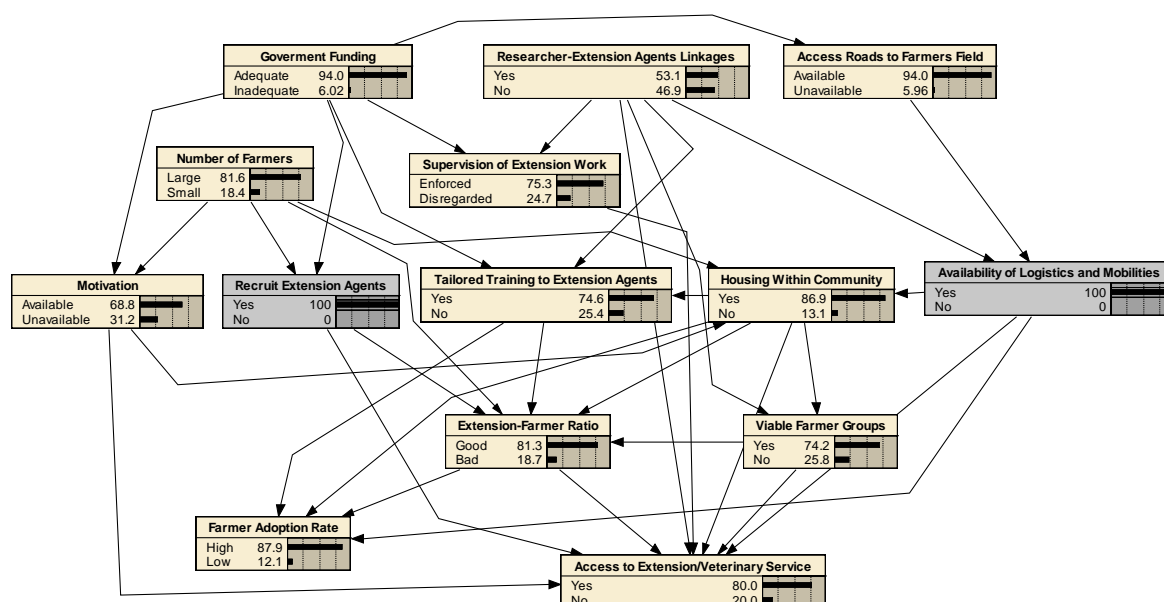
Figure 5.4c: BBN modelling for increasing access to extension/veterinary service

(With intervention: recruit extension agents and making logistics and mobilities availability)

The government provision of logistics and mobility such as access roads and vehicles will improve the working conditions of the field agents. In addition to the provision of housing within the community and functional supervision systems, these will facilitate extension agents' access to farmers, and vice versa, thereby positively affecting the agricultural system.
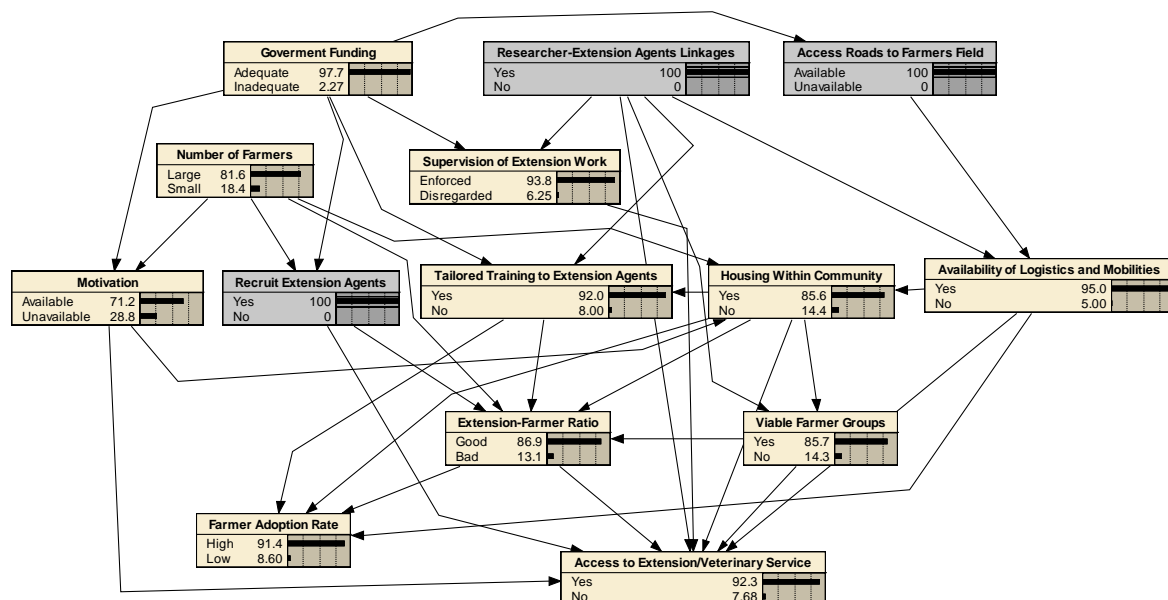
Figure 5.4d: BBN modelling for increasing access to extension/veterinary service

(With intervention: recruit extension agents, improving research-extension agents' linkages and creating access roads to farming field)

Sufficient investment in extension staff recruitment, researcher–extension linkages and access roads will increase the probability of improved access to extension services by as much as 92.3% (see Figure 5.4d). The flow of information from agricultural research to farming communities and vice versa requires extension agents. Extension officers remain the link between researchers' outputs and farmers' information needs to increase agricultural productivity. The link can be strengthened in several ways, including improved collaboration between research and extension, and the research needs to be packaged in such a way that it will meet farmers' needs and understanding. Extension agents require skills and knowledge to examine and meet the needs and research demands of farmers.

Access to research output and extension services is crucial for rural and agricultural development in Ghana and Africa at large. Further, good roads and transport services will augment farmers' quality of life, thereby ensuring access to income and basic services such as local and regional markets, agricultural extension centres, clinics and schools.

Results of the BBN model (see Figure 5.4d) indicate that, with these interventions, the probability of farmer adoption rates will improve from 50% to 91.4%. Farmers' chances of forming long-lasting farmer groups will increase from 53.8% to 85.7%. The likelihood of the extension–farmer ratio improving will increase from 59.9% to 86.9%, while the probability that extension staff will become motivated will increase from 37.5% to 71.2%.

5.3.2.1.2 Bayesian Belief Network Modelling for Increasing the Agricultural Productivity of Farmers

Agricultural productivity has long been a challenge for Ghanaian farmers and Africa as a whole, especially in the face of compounding complex issues that negatively affect profitability and food security. Improving agricultural productivity was identified as a key leverage point for improving farmers' welfare and food security. A BBN model (see Figures 5.5a–f) was developed to determine the interventions that could result in increasing farmers' agricultural productivity. The BBN model (see Figure 5.5a) indicates the likelihood of the current agricultural productivity as 57.5%, and 55.9% as farmers above the poverty line.
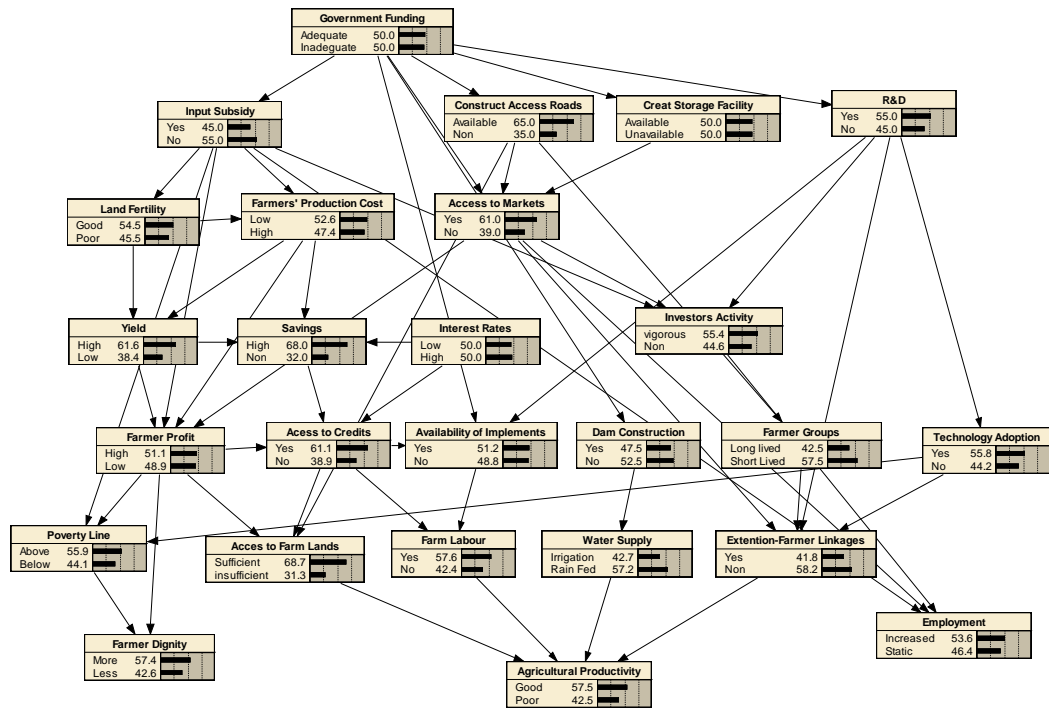
Figure 5.5a: BBN modelling for increasing agricultural productivity

(Current situation)

Table 5.5: Explanations of some key variables in Figure 5.5a BBN

Agricultural productivity	Agricultural productivity is the term given to the output of agriculture in terms of the inputs such as the capital and labour. This could also be defined as the efficiency of the farm.
Access to farm lands	Access to arable land especially in areas close to the cities and market centres in Africa in general is currently witnessing intense competition from urbanisation and infrastructure development.
Poverty line	The poverty line is the minimum level of personal or family income below which one is classified as poor according to governmental standards. Extreme poverty is defined as living on $1.25 or less a day.
Farmers' dignity	When farmers' crops or marketing fail, they lose everything and become servants to the moneylenders in the community they leave. They then lose their dignity and respects when they cannot afford responsibilities.
Employment	Employment is induced directly by constructing access roads to farming communities where accessing markets become easier to provide goods and services to meet consumption demands and indirect by those employed in supplying inputs to farm or other projects.
Dam construction	Dam construction will increase year round water supply for agricultural irrigation to increase productivity and production efficiencies.
Investors activities	Government's investment in public goods such as rural roads, agricultural research and extension services, and rural schooling, clean water and health can favour or induce environment for investor activities in agricultural development.
Input subsidy	Subsidies often provided by the government can help overcome poor farmers 'inability to obtain credit or take risks or reduce his production cost.
R&D	Lack of investment in research and development (R&D) of Africa's agriculture means that the continent remains largely dependent on outside funding. Africa's population is expected to rise from one billion today to 2.1 billion by 2050 — under-investment in agriculture is sure to undermine the continent's economic growth.
Access to credits	Farmers cannot get access to credit, insurance and inputs because of they lack collaterals and also as a result of market failures for their crops.

Figure 5.5a shows that the probability that farmers' yields and profits are high are 61.6% and 51.1% respectively. The likelihood that farmers' adoption rates will be good is 55.8%, while the probability to save is 68.0%. As a result of their social–political–economic status, the probability that farmers' dignity will be high is 57.4%, and 57.5% of farmers are actively employed in the farming business.

The BBN model (see Figure 5.5a) was used as a decision model to test the possible outcomes of the following systemic interventions strategies: government funding, accessible input subsidy and farm implements, construction of access roads, active research and development, and dam construction.

Government Funding
Adequate 78.9
Inadequate 21.1

Input Subsidy
Yes 59.5
No 40.5

Construct Access Roads
Available 73.7
Non 26.3

Creat Storage Facility
Available 67.4
Unavailable 32.6

R&D
Yes 69.5
No 30.5

Land Fertility
Good 55.9
Poor 44.1

Farmers' Production Cost
Low 56.7
High 43.3

Access to Markets
Yes 75.5
No 24.5

Yield
High 63.7
Low 36.3

Savings
High 69.9
Non 30.1

Interest Rates
Low 50.0
High 50.0

Investors Activity
vigorous 69.9
Non 30.1

Farmer Profit
High 62.4
Low 37.6

Acess to Credits
Yes 63.8
No 36.2

Availability of Implements
Yes 69.7
No 30.3

Dam Construction
Yes 100
No 0

Farmer Groups
Long lived 46.8
Short Lived 53.2

Technology Adoption
Yes 65.2
No 34.8

Poverty Line
Above 66.4
Below 33.6

Acces to Farm Lands
Sufficient 74.7
insufficient 25.3

Farm Labour
Yes 68.8
No 31.2

Water Supply
Irrigation 90.0
Rain Fed 10.0

Extention-Farmer Linkages
Yes 51.5
Non 48.5

Employment
Increased 67.8
Static 32.2

Farmer Dignity
More 68.0
Less 32.0

Agricultural Productivity
Good 72.7
Poor 27.3

Figure 5.5b: BBN modelling for increasing agricultural productivity

(With intervention: dam construction)

Dam construction will increase the probability of higher agricultural productivity from 57.5% to 72.7% (see Figure 5.5b). According to the farmers, dam construction will supplement water supply, especially during the dry season, and will reduce their dependency on rain-fed agriculture. Dams can also store rain harvest and recycle irrigation runoff from farming areas, thereby retaining both water and nutrients for reuse that would have otherwise been lost. Dams will also provide an opportunistic use for a range of water sports, including boating and fishing as a secondary activity.

Figure 5.5a shows that the likelihood percentage of the Ghanaian population living below the international poverty line of $1.25 (in purchasing power parity terms) per day is 44.1% (Olinto et al. 2013; UNDP 2012a). More than one-quarter of farmers involved in the workshops live below the poverty line and have a household income of less than US$400 a year, and one-third of these failed to make a profit. Three out of four of those below the poverty line depended on agriculture for their livelihoods; however, with dam construction and other intervention strategies, farmers living below the poverty line may reduce from 44.1% to 13.5% (see Figure 5.5f). Many farmers diversified or engaged in off-farm activities such as mat/basket weaving, illegal mining activities and charcoal production or manual stone quarrying as a way to earn money away from the farm to survive. This helps them to enhance their standard of living and that of their family, and to retain and improve their dignity within

their community. The empirical evidence (see Figure 5.5b) shows that constructing a dam as an intervention will increase the probability of agricultural yield and farm profit from 61.6% and 51.1% to 63.7% and 62.4% respectively, thereby leading to a probable increase in farmers' dignity from 57.4% to 68%. Figure 5.5b also shows that the chance of farmers actively employed in farming business will increase from 53.6% to 67.8%, as well as an increase in the likelihood of adoption from 55.8% to 65.2%.

Figure 5.5c: BBN modelling for increasing agricultural productivity

(With intervention: construct access roads)

Access roads to farms and markets are critical for raising agricultural productivity, as shown in Figure 5.5c. In the absence of feeder roads, the cost of moving produce and hiring mechanisation increases. As a result, smallholder farmers rely heavily on manual labour using cutlasses and the hand hoe as their main implements for crop production. Livestock continues to rely on natural pastures. *Ad hoc* and uncoordinated agriculture production is the order of the day as a result of unavailable power, especially where manual labour resources are depleted by age, migration and food insecurity. As a result, crop production takes place within four to six hours' travel time from the central markets.

Availability of agricultural implements also influences farm productivity, as shown in Figure 5.5d. Usage of animal traction has declined in Ghana agriculture systems in the past 6 decades.

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Tractors are the main farm machines used for tillage operations; however, access to both mechanised and non-mechanised farm implements is difficult, making agriculture yet more reliant on manual methods. Small-scale farmers in Ghana cannot justify the ownership of a tractor for exclusive use due to financial constraints. In some cases, a whole district has only one functional tractor, and some districts have none. Private owners of mechanised farm implements do not hire their implements to locations where there is no good road network to ply, and where feeder roads are available; tractor operators have to travel long distances to reach farmers' fields, thereby increasing the hiring cost. As tractor operators are not utilised to their full capacity after long-distance travel, small farmers are forced to form cooperatives for the collective use of a tractor to justify the costs associated with long-distance travel. These constraints place severe limitations on the amount of land that can be cultivated per family. As a result, more time is spent on the farm with limited efficiency, thereby reducing crop yields and productivity.
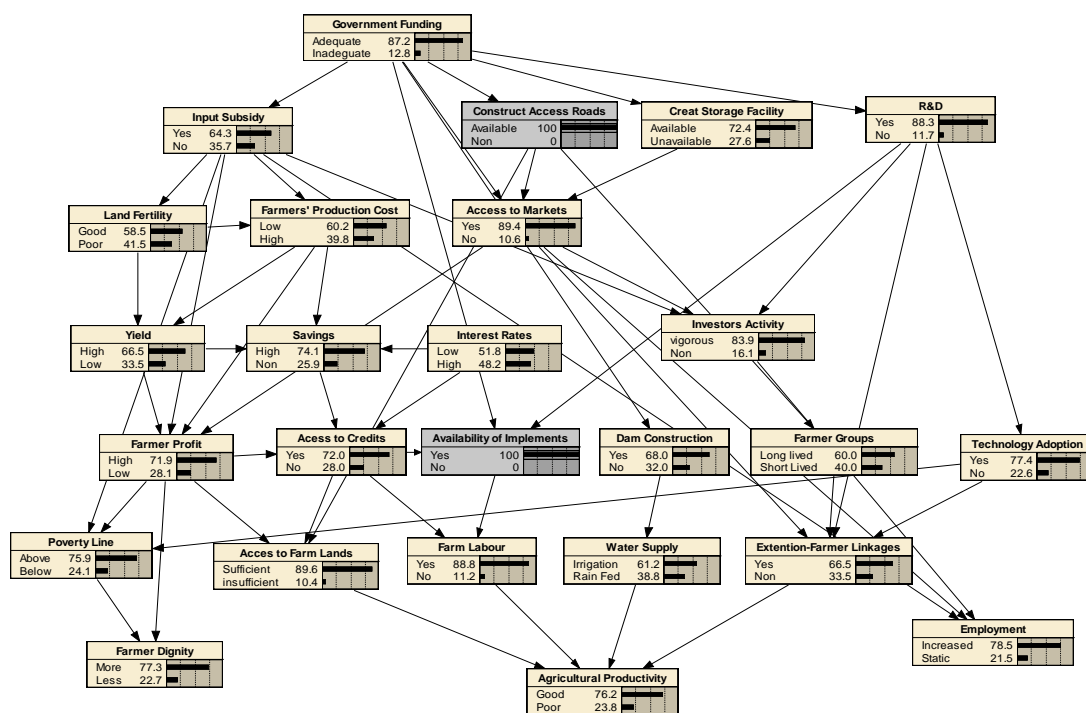
Figure 5.5d: BBN modelling for increasing agricultural productivity

(With interventions: construct access roads and making farm implement available)

The construction of a dam and access roads with available farm implements could result in a probable boost of agricultural productivity by 45.6%, as shown in Figure 5.5e.

The scarcity of agricultural input markets in farming communities is a major constraint to productivity growth. According to the farmers, agricultural input subsidies (fertilisers and improved seeds) will induce their likelihood of adoption of innovations and make them more competitive, thus increasing agricultural productivity (see Figure 5.5f). However, subsidies do

not address the root causes of unavailable inputs due to high cost, and they are unsustainable fiscal costs for the Ghanaian economy.

According to the workshop participants, most subsidies tend to benefit cocoa farmers and political supporters of the ruling party other than the horticultural or animal husbandry sectors. While input subsidy may be a short-term solution, a remedy is designed to address the root cause. Poor agricultural practices have aggravated soil endowments and damaged soil properties. There is broad consensus that substantial increases in inorganic fertiliser use are necessary to restore and maintain the fertility of Ghanaian soils and enhance their productivity. However, the use of chemical fertilisers must be integrated with the good agricultural practices approach.
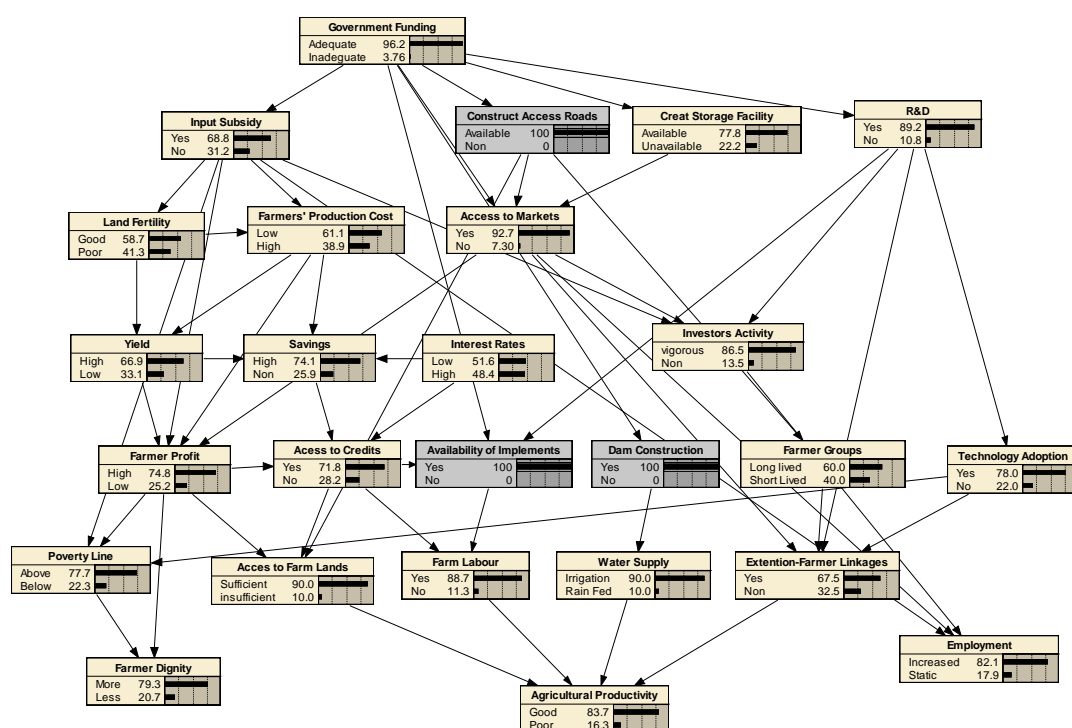
Figure 5.5e: BBN modelling for increasing agricultural productivity

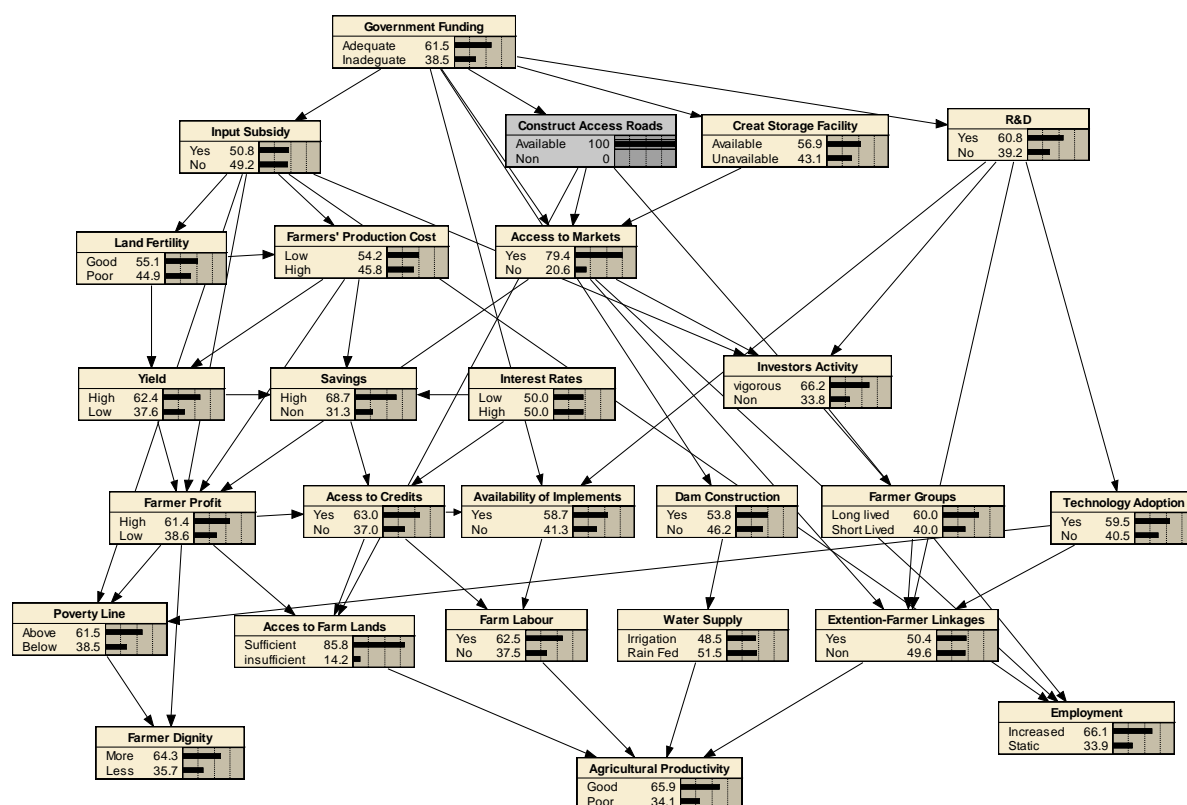*(With interventions: construct access roads, making farm implement available and dam construction)*
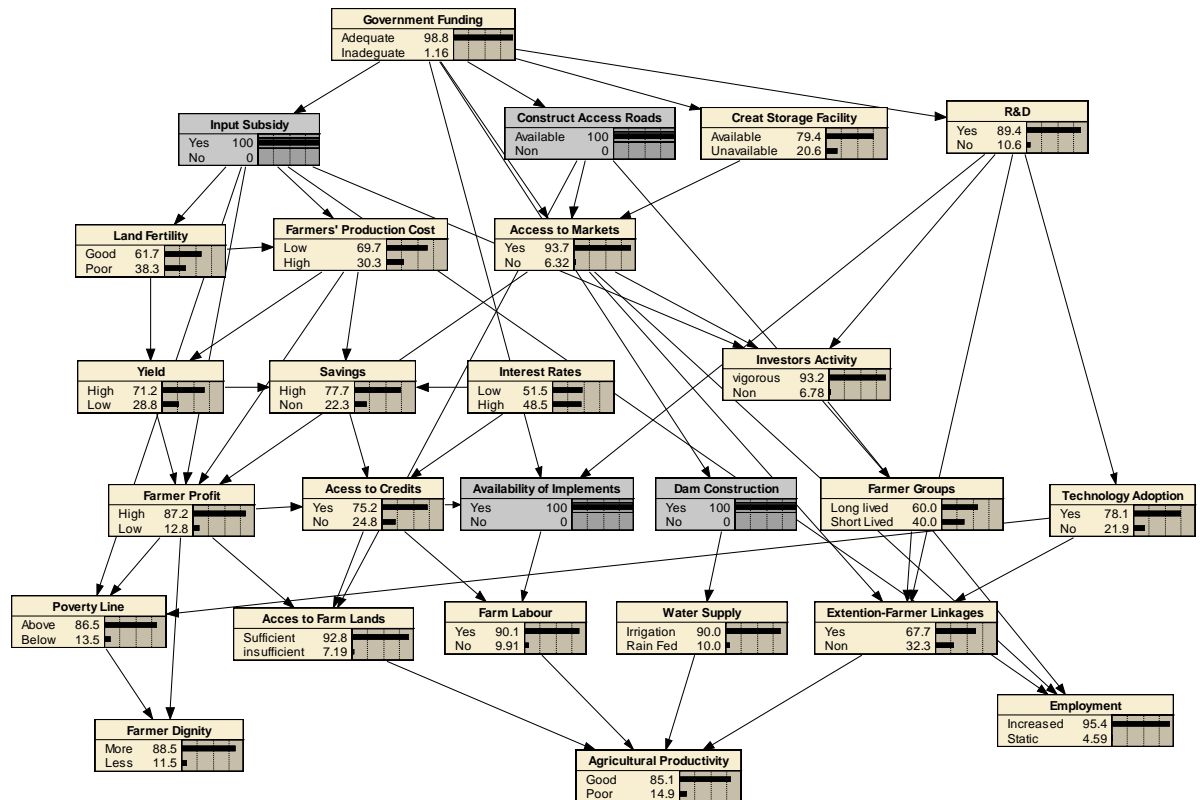
Figure 5.5f: BBN modelling for increasing agricultural productivity

(With interventions: construct access roads, making farm implement available, dam construction and input subsidy)

With these interventions (dam construction, access roads, available farm implements and subsidy), the BBN model (see Figure 5.5f) indicates the probability that agricultural productivity levels will rise from 54.4% to 85.1% and reduce poverty levels from 44.1% to 13.5% below the poverty line. The poverty estimated among farmers who participated in the workshops revealed that 26% were below the poverty line; with these interventions, it is likely to decrease to less than 8%. Figure 5.5f also indicates that the probability that farmers' yields and profits will increase is high, from 61.6% and 51.1% to 71.2% and 87.2% respectively.

5.3.2.1.3 Bayesian Belief Network Modelling for Increasing Entrepreneurship among Actors

The economic and social situations of a country provide a framework for development activity by the private sectors, which contribute significantly to achieving economic growth and job creation. Promoting business developments and entrepreneurship remain high on the Ghana Government's agenda of policy debates and research for improving the prospects for urban small enterprise development. However, according to respondents, the business or investment climate confirms a pattern of generally low productivity and suggests significantly high indirect costs in suppressing the productivity of Ghana's firms relative to Western countries. In designing and addressing interventions to enable actor businesses to bloom or to

induce entrepreneurship, it is critical for the government to provide enabling environments as key leverage points. Subsequently, a BBN model (see Figure 5.6a–d) was developed to explore these statements.

The BBN model (see Figure 5.6a) indicates that the probability of the current level of entrepreneurship among actors in the agricultural industry is 48.8%, with the chance of unemployment as 27.5%. The likelihood of job creation is 58.5%. Figure 5.6a also indicates that the current probability level of establishing new industries or companies is 64.0%, while the probability of quality of input supply is 49.7% and the chance of receiving a high level of education and training is 68.3%.
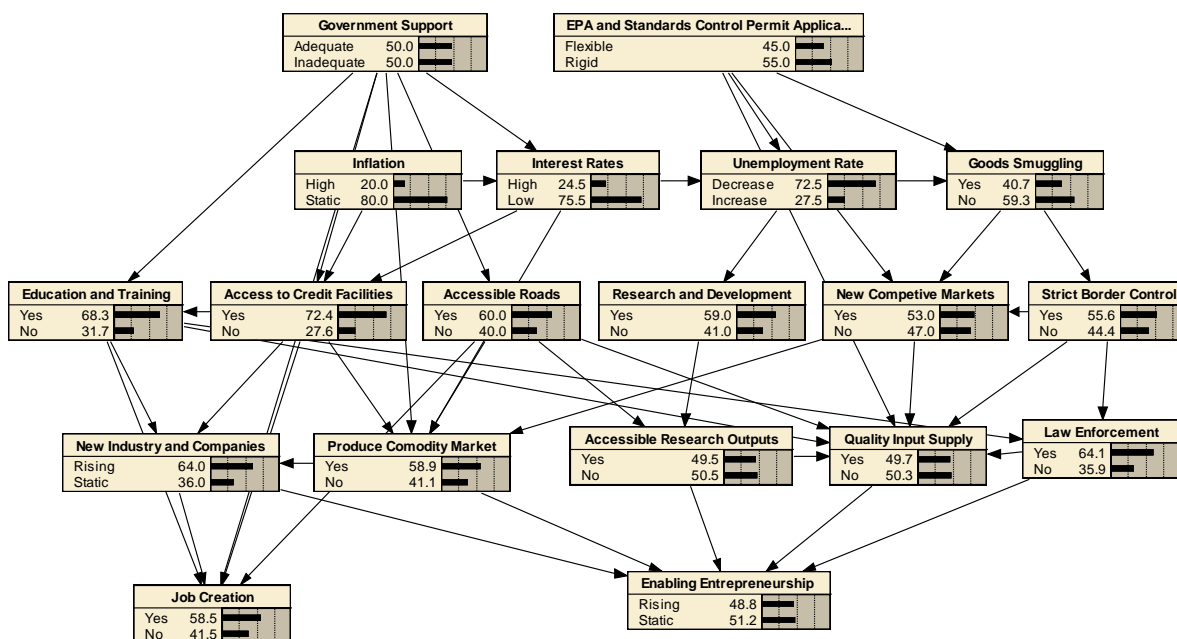
Figure 5.6a: BBN modelling for enabling environment to induce entrepreneurship

(Current situation)

Table 5.6: Explanations of some key variables in Figure 5.6a BBN

Enabling entrepreneurship	Creating an enabling environment for private sector or entrepreneurship development is important in reducing administrative cost of doing business. Government regulations as well as difficult access to property titles are some of the most important entrepreneurship growth constraints.
EPA and standards control permit application	EPA oversees the implementation of the National Environment Policy. It mission is to manage, protect and enhance the country's environment and seek common solutions to global environmental problems. The Ghana standard authority promotes standardisation for the improvement of the quality of goods, services and sound management practices in industries and public institutions in Ghana. To do agricultural related business in Ghana, requires permit application from these two bodies
Goods smuggling	Lax border control allows others to smuggle into the country fake and poor quality agricultural inputs which affects local market.
Produce commodity market	Produce commodity market often regulated by the government ensures legal framework that allow security and commodity exchanges in the country to promote agricultural investment.

The BBN model (see Figure 5.6a) was used as a decision model to test the possible outcomes of different systemic intervention strategies, including developing access roads, increasing the budget for research and development (R&D), and creating new markets. The three management objectives as discussed (see Figures 5.4d, 5.5c and 5.6b) and indicate that access to roads are pivotal to increasing productivity, farmers' access to extension services and creating an enabling environment for entrepreneurship. Thus, critical intervention by the government to create access to roads is important in fostering mobility access to promoting the development of markets and reducing poverty in Ghana. As shown in Figure 5.6b, access to roads can increase the current probability of entrepreneurship from 48.8% to 62.7%, with the chances of creating jobs rising from 58.5% to 76.1% and the likelihood of decreasing unemployment from 27.5% to 26.3%.

Figure 5.6b: BBN modelling for enabling environment to induce entrepreneurship

(With intervention: accessible roads)
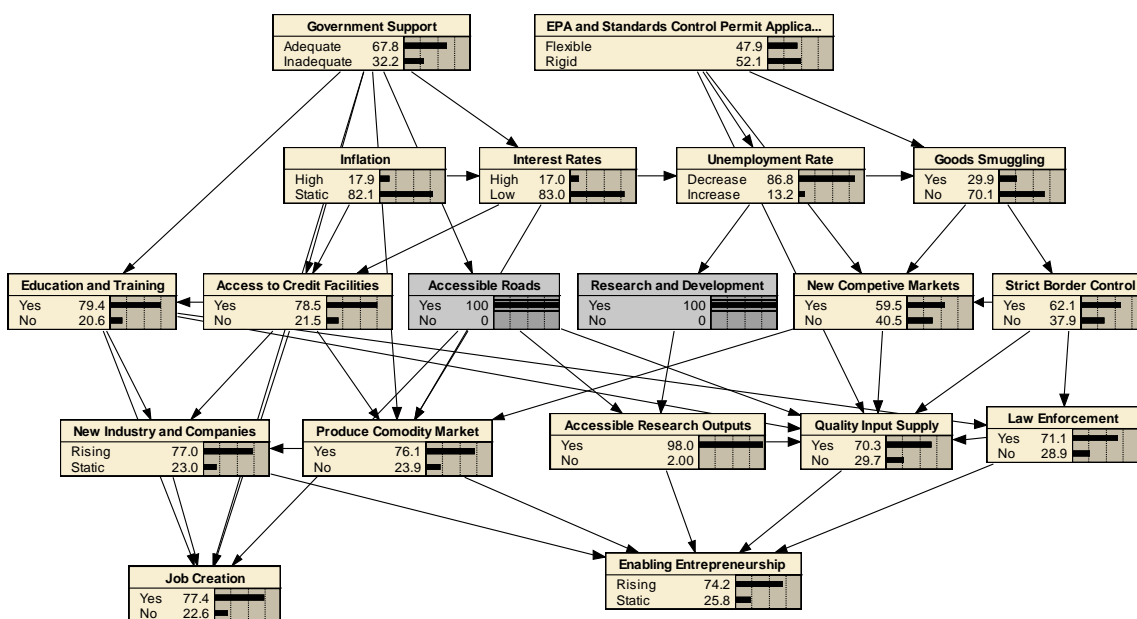
Figure 5.6c: BBN modelling for enabling environment to induce entrepreneurship

(With intervention: accessible roads and research and development)

R&D is essential for promoting entrepreneurial activities in Ghana and Africa as a whole. Government intervention through sufficient budgets for R&D institutions is essential to stimulate incremental innovation in technological or non-technological processes. Investment in R&D increases the likelihood of enabling the climate for business activities by more than 18% (see Figure 5.6c). Firms' integration of novel technologies in both processes (production techniques or the supply of goods and services) and products (design of goods and services), or of non-technological innovations relating to organisations or commerce (e.g., new practices

in work organisation, improved use or sharing of information, knowledge or skills within enterprises, adoption of new organisational methods to optimise decision making and the sharing of responsibilities), is known to be one of the most important factors for facilitating the development of entrepreneurship skills and helps to provide an enabling environment for entrepreneurial activities. Investment in R&D will also increase the likelihood of education and training, as shown in Figure 5.6c. Education and training are seen as being very important for developing an entrepreneurial attitude and culture, especially among the youth for creating and consolidating enterprises.

Farmers and firms' integration of technological novelties can be challenging with limited local or regional markets. Thus, government intervention in new market developments will induce the enabling environment, as demonstrated in Figure 5.6d, to promote a favourable business and investment climate.

Implementing these interventions (i.e., access roads, R&D, and development of new markets) could result in the chance of actors' businesses blooming and changing the likelihood of entrepreneurship induction from 48.8% to 80.5%. The probability that new industries and companies will be initiated will increase to 80.2% from 64%, subsequently raising the probability of more job creation from 58.5% to 79%. With this progress, the likelihood that border goods smuggling will be curtailed is high, decreasing from 40.7% to 8.4%, thus reducing unemployment likelihood to 4.4% from 27.5%. The probability that the level of input supply quality will improve will also increase from 49.7% to 83.7%.
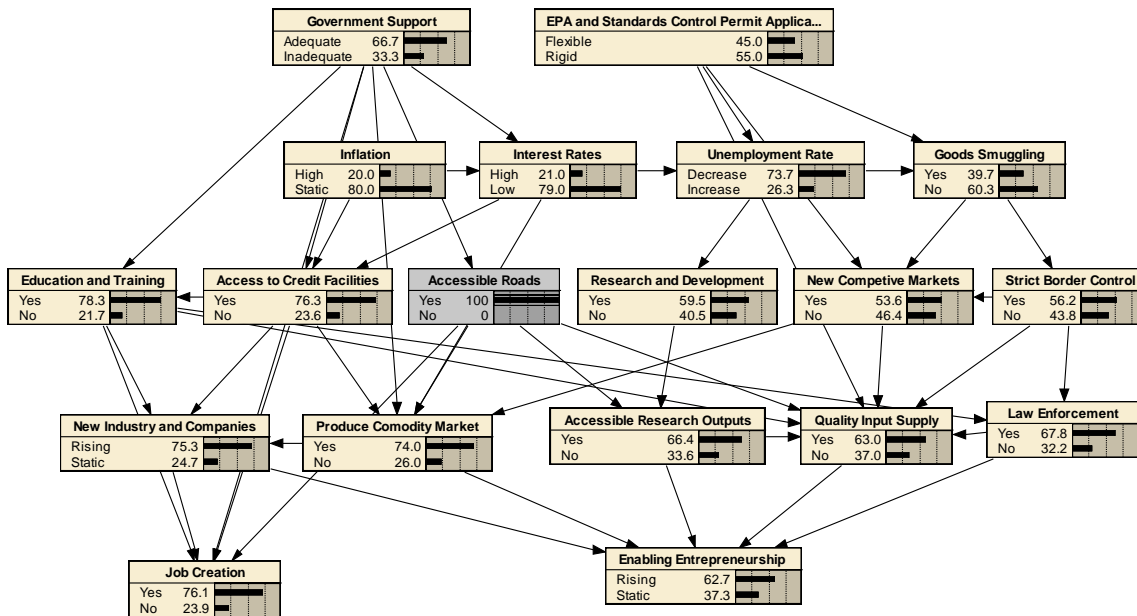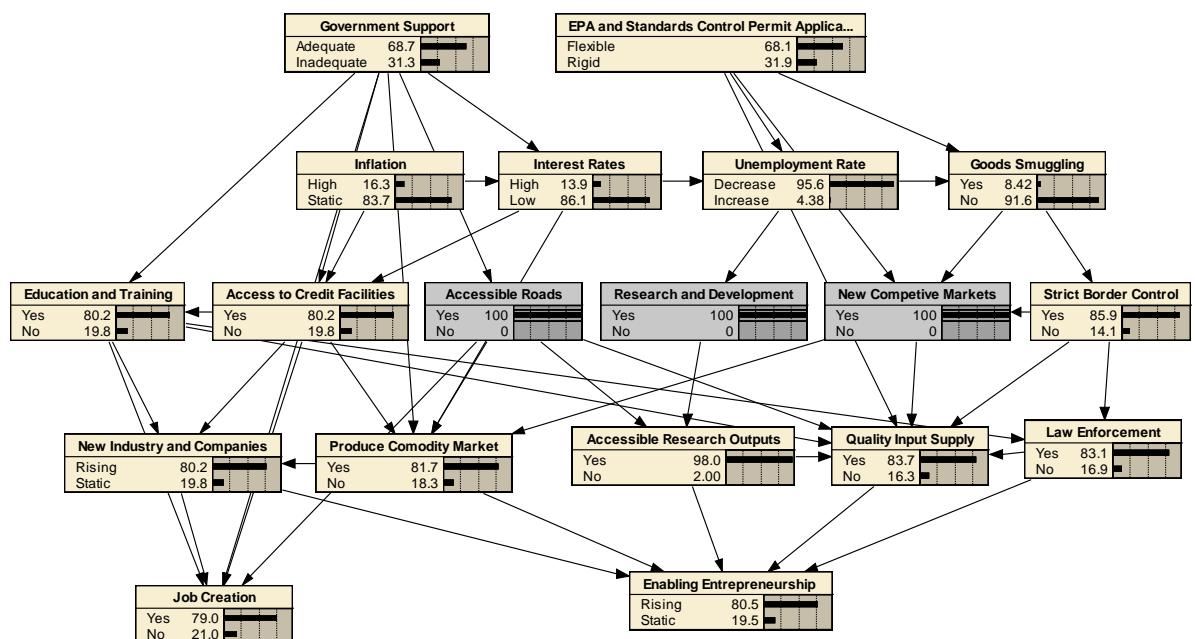

Figure 5.6d: BBN modelling for enabling environment to induce entrepreneurship

(With intervention: accessible roads, research and development and new market competitive markets)

5.4 Conclusion

Capacity-building and governance using a systems thinking approach and the ELLab in business decision-making processes and policy analysis has proven to be effective in understanding complex design problems. Results from the BBN models indicate that the implementation of systemically determined interventions, policies and strategies could result in high chances that the agriculture industry will evolve, improve and raise its efficacy not only in Ghana, but also in Africa and the world at large. This would also lead to a significant increase in the yields and profits of farmers and actors. As demonstrated in the previous CLDs, systemic approaches will significantly help agriculture to remain the engine that develops and empowers the emerging and existing commercial agribusiness sectors and entrepreneurs across Africa. This approach could serve as a complementary tool for African governments and agriculture proponents to analyse and test the possible outcomes of different policy interventions by observing what would happen to the system as a whole when a particular strategy or combination of strategies is implemented—that is, before any time or money is invested in implementation. This will help to eliminate or minimise the waste of scarce resources and unintended consequences associated with funding R&D. For Africa and the rest of the world to leave behind complex challenges resulting in famine, pestilence, war and terrorism, we need to move past the information stage to revelation knowledge. For African governments to make the right management decisions in the face of a continually changing political and socioeconomic landscape, they must ensure that policy documents pass a systemic test to prevent failure in the long run. The root causes of African challenges are easy to identify; however, for many decision makers and policymakers, they are completely hidden from view. To resolve today's challenges, decision makers and policymakers must move away from the traditional approach to addressing challenges towards a systems perspective that addresses the root causes rather than the symptoms.

At the most fundamental level, this requires moving from a 'linear' way of thinking—focusing on quick fixes—to a systems perspective, where decisions are scrutinised through systemic tests to bring thought and behaviour in line with the natural laws of sustainability. It is essential for advocates to know and be able to perceive that they are working within a complex web of interdependent systems that reflects the mental models of its inhabitants or stakeholders. Aid and trade are inadequate to end Ghana and African poverty. A change in the mental structures of stakeholders and policymakers, knowing and understanding the root causes of challenges, and knowing how to intervene will make overt the challenges that are often ignored. Systems thinking offers a range of analytic tools to improve our capacity to think systemically, including ways to distinguish problem symptoms from root causes.

However, in an emergency situation, quick fixes can be used to address the problem systems in the short run before leverage points are identified to deal with the problem's root cause. Applying systemic tools enables us to target high-leverage interventions that can lead to sustainable, system-wide improvement. Short-term successes in emergency situations are frequently not sustained, and the problem reappears (Thomas 1979).

In Ghana's agricultural industry, there is fairly broad agreement that increased investment in key public goods such as access to roads from farms to markets, investment in agricultural extension services, agricultural research and water control (dam) will be required if revitalised agricultural development is to take place. However, how it should be done must involve all stakeholders, as demonstrated in the BBN models. As the BBN models are connected with cause-and-effect links, the ripple effect of interventions is transmitted right through the whole system—positively or negatively—in accordance with systems component relationships and interconnections. The developed models reveal the sources of complexity affecting the performance of agricultural development that has given rise to the poor sustainable economic development within Ghana's agricultural communities. It also serves as a platform for addressing complex challenges and managing policy in addition to social, economic and environmental development in Ghana and Africa. Based on the previous analyses, it is evident that the models can be used as decision-support systems, where one can learn and adapt more effectively than in other approaches, which do not use systemically determined decisions for adaptive management.

Overall, this research approach is adaptable and can be applied to address complex challenges facing the performance of agricultural development not only in Africa, but also in agricultural communities around the world. This approach provides more clarity on dealing with the complex sustainability challenges and should rapidly replace the traditional lineal way of dealing with challenges and forming policies. The approach makes overt the challenges that are often ignored and will help decision makers and policymakers to anticipate the long-term consequences of their decisions and actions, as well as help to avoid any unintended consequences of policies and strategies. The ELLab offers a methodology for creating informal learning platforms for managing complex issues and ensures that stakeholders take ownership of the solution because it is their own mental model and, in the long run, it ensures adoption and implementation.

The results of this research reveal the root causes of the challenges and identify key leverage points where their investments will have the biggest effect. Key leverage points can also serve as the intervention points within the agricultural system for governments, policymakers, other development agencies such as the World Bank, the FAO and NGOs, and they will ensure

good policies for sustainability. The models can also be used for scenario testing to develop and test alternative government budget formulation and management policies, which will significantly help in the proper allocation of a country's scarce resources. Complexity is often a concept or condition that seems too difficult to deal with, but this research has shown that, with systems thinking tools, dealing with complexity has become much easier than is normally anticipated. There is a need for capacity-building in the application of systems thinking and dynamics among governments in Ghana and Africa as a whole to move to a new way of thinking in policy formulation and development.

5.5 Acknowledgements

Chapter 6: Paper Five: The greater push model for growth and sustainability

A systems thinking approach: 'the greater push model' for growth and sustainability in Africa—evidence from Ghana

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Abstract: Over six decades, agricultural policies attempting to increase the competitiveness of project performance had limited success. This is due to the use of traditional project management methods that do not address the complex challenges encountered in a systemic way. This paper provides an example of how a systemic approach is applied to agricultural development. The findings are based on a series of workshops conducted in Ghana in 2013 and 2014. Findings include an established community development model, the 'greater push' and a new way of measuring, monitoring and evaluating sustainable development with Bayesian belief network modelling that satisfies the 'Bellagio principles' for measuring sustainable development indicators. This research contributes to systemic application in project management and can help policy-makers across the world to identify threats to sustainable economic growth and help them to anticipate unintended consequences of their decisions and actions before it is too late to reverse the trend.

Keywords: agriculture; development model; economic growth; policy-makers; systems thinking; sustainable development; development indicators; adaptive management.

Statement of Authorship

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Name of Principal Author (Candidate)	Kwamina Ewur Banson
Contribution to the Paper	The conception and design of the manuscript, establishing methodology, conducting workshops in the study area for data collection and models validation in Ghana. Compiling, analysing and interpreting data, working on the development of the first draft manuscript and the writing and submission of the final version.
Overall percentage (%)	85%
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature	Date 22/06/2016

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

    i.   the candidate's stated contribution to the publication is accurate (as detailed above);

    ii.   permission is granted for the candidate to include the publication in the thesis; and

    iii.   the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Nam C. Nguyen (Principal Supervisor)
Contribution to the Paper	Supervising and assisting with the establishment of methodology, planning of the survey, discussions, supervising development of first draft, editing and co-authoring the manuscript.
Signature	Date 27/06/2016

Name of Co-Author	Ockie J. H. Bosch (Co-Supervisor)
Contribution to the Paper	Supervising and assisting with the establishing of methodology, editing and co-authoring the manuscript.
Signature	Date 28/06/2016

Please cut and paste additional co-author panels here as required.

6.1 Introduction

Agriculture and its related industries are vital components not only for Africa, but also the world's developing economy (Porter 2000). More than 90% of Africa's producers are small-scale farmers who have limited access to resources compared to their competitive counterparts in developed countries (Leichenko & O'Brien 2002; Mead 1994). It is imperative that agricultural producers continue to be economically and environmentally sustainable, as these enterprises provide the products that increase their quality of life and provide access to safe and nutritious food (Leichenko & O'Brien 2002; Mead 1994; Sun, Hyland & Cui 2014). African agricultural producers and proponents face increasing challenges, including distorted knowledge, the use of traditional approaches, deteriorating infrastructure, climatic extremes, environmental pollution, social disintegration, loss of community, crime and violence, urban blight, and unmanaged growth (Banson et al. 2013; Godfray et al. 2010; Tripp 1993). Agricultural extension officers educational programs hardly provide farmers with systemic (targeted to their real needs) research-based knowledge vital to improving their sustainability and profitability (Rola, Jamias & Quizon 2002). Most communities do not have established food supply chain systems that can deliver produce from farms to consumers (Dolan & Humphrey 2000; Feenstra 1997; Weatherspoon & Reardon 2003). Food system development includes farmers' markets, community gardening, food hubs, processors and wholesale/direct market development.

Many initiatives have been proposed by the World Bank, FAO, governments, research institutions and NGOs to address and modernise the agricultural sector in Africa, but with little success (Banson, Nguyen & Bosch 2015a; Banson et al. 2015; Havnevik et al. 2007; World Bank 2013b). Most funded R&D activities only lead to unintended consequences that far outweigh the expected benefits because they either shift the problem to another sector or give rise to a much bigger problem to be fixed later (Banson et al. 2015). For example, a 270% increase in agricultural land resulted in only a 70% increase in productivity (Banson et al. 2015; Oxford Business Group 2010). In 1975, the World Bank published 'Rural Development in Africa', which was the bank's initiative to counteract food shortages and unequal income distribution (Banson et al. 2015; World Bank 2013b). Then, in January 1985, the World Bank donated $5 million within the space of a single year to the World Food Programme for emergency food supplies to Sub-Saharan Africa (Banson et al. 2015; World Bank 2013b).

This indicates that the initial World Bank intervention gave rise to a much bigger problem, and its approach could not fortify the sector.

Productivity levels have been declining since 1960 (Banson et al. 2015). Governments and agriculture proponents currently have neither adequate information nor the necessary tools to analyse and measure the sustainability and performance of policies affecting the food and agricultural sectors (Banson et al. 2015). Indigenous and global problems and challenges facing the agricultural sector today are highly complex in nature (Banson et al. 2015; Bosch et al. 2013; Nguyen & Bosch 2013). Sustainable development is crucial to global food security and economic health, but current tools with traditional approaches cannot synchronise development models with their development indicators for simulations to test the possible outcomes of different interventions before any time or money is invested in implementation. This has led to billions of dollars being wasted by the World Bank, FAO and agricultural proponents including NGOs and governments (Banson et al. 2013). As made known by past interventions, these problems and challenges cannot be addressed and solved with traditional approaches, which study complex systems by breaking them down into their separate elements. Thus, there is a need for a new approach to interventions in development projects and the agribusiness that can both identify relevant indicators and predict the unintended consequences associated with any intervention before investment. The systems thinking approach provides the tools that can highlight and address problems using integrated approaches, and it can demonstrate how to translate difficult ideas into potent management tools for change. The evidence of successful systems thinking application can be seen in various fields and disciplines, but its application to agricultural sustainability management is yet to be explored by many researchers, managers and policymakers in Africa (Nguyen & Bosch 2013).

Access and adoption of the 'systems thinking' approach and systems tools, new production practices, alternative crops, new marketing options, and a trained labour force will result in viable agricultural sustainability and productivity. This will ensure continuous profitability that can contribute to the economic growth not only in Africa, but around the whole world.

6.1.1 Importance of Sustainability Measurements

Many publications could provide guidance towards improving the quality of life among agricultural stakeholders in Africa; however, most solutions are based on theory, which is a supposition established upon ignorance of the subject under discussion (Bukusuba, Kikafunda & Whitehead 2007; Downing et al. 1997; Hagin 2012; Thompson Klein 2004; Wester, Merrey & De Lange 2003). Achieving sustainability and competitiveness has not been explored much, especially in regards to systemic interventions. Osborn (2002) defines sustainable development as a means to manage growth in the world's economies during the next century in a way that avoids disaster for the environment and reduces the intolerable

gaps between the 'haves' and 'have-nots'. Sustainability in the context of this paper is defined as the provision of the minimum necessary resources for community use to initiate development and ensure community welfare and that of others. The ability to efficiently use state land, water, human and other resources to achieve sustainable improvement in the standard of living and growth in productivity for all stakeholders will define competitiveness (Tilman, Wedin & Knops 1996). This will further provide a platform for agricultural and economic growth, employment creation, and national prosperity through the art of interconnected thinking, increased innovation, productivity, investment and trade.

Private and public organisations have experienced significant changes in recent years in both size and complexity (Banson 2015). As a result, it is no small task to develop and perfect a system for sustainability measurement (Aucoin 1990; Meadows 1998). Consequently, the management process has become more difficult and requires greater skills in analysis and planning, as well as knowledge of the control skills aimed at guiding the future course of organisations faced with accelerating rates of evolution in technical, social, political and economic forces (Dodgson et al. 2011; Hilbert 2013; Keegan & Nguyen 2011; Mingers & White 2010; Nguyen, Bosch & Maani 2011; Smith 2011; Stalk, Evans & Sgulman 1992; Zeleny & Cochrane 1982). There is currently much debate about the most effective way to measure and track corporate sustainability progress and the choice and use of indicators (Berns et al. 2009; Chamberlain 2014; Hilbert 2013; Meadows 1998). Sustainable economic development is a topical issue that has attracted the attention of governments, policymakers, academics and professionals around the world (Raimi & Ogunjirin 2012). The importance of this concept cannot be overemphasised, especially if one takes into account the number of summits, conferences and seminars that have been held to discuss the importance of sustainable development for the benefit of both developed and developing nations. Using precise metrics, sustainability efforts can be perceived as a major indicator for systems health, stability and its long-term prospects (Hilbert 2013; Mingers & White 2010). Indicators of sustainable development need to be developed to provide solid bases for decision making at all levels, and to contribute to the self-regulating sustainability of integrated environment and development systems (Meadows 1998). However, due to its vagueness and unclear measurement, sustainability is not incorporated in any financial valuations or investment decisions.

6.1.2 Why Systems Thinking?

'Systems thinking' is a scientific approach involving the art of interconnected thinking and a set of tools to deal with complexity, ambiguity and the integration of mental models into systems structures. It suggests moving away from the information stage (i.e., seeing single elements and events) towards revelation knowledge (i.e., seeing the processes in which they interrelate). The systems thinking approach provides insights into the structure and behavioural patterns of organisations. These help to reveal the root causes of challenges, plan the future, reduce risk, anticipate delays and prevent unintended consequences (Banson, Nguyen & Bosch 2014; Highsmith 2013).

Systems thinking gives rise to a new art of thinking required in business, management and finance, as well the technical aspects of managing economic development for the 'Greater Push' effects. The 'big push' model developed by Rosenstein-Rodan (1957) and further refined by Murphy et al. (1988) accelerates economic development. The study also adapted this model for a 'greater push' model for growth and sustainability in agricultural production systems. The 'greater push' model assumes holistic thinking and interrelationships to the extent that any small effect of productivity on one sector affects the whole system. This is in contrast with the 'big push' model, which assumes that any small increase in the productivity of one sector has no effect on the economy as a whole.

Agricultural stakeholders and organisations are often counselled to develop strategic alliances that can address changing demand and sustained environments while improving the quality of life (Brester & Penn 1999; Cornelissen & Durand 2014). A systemic approach to strategic agricultural management implies that the natural and human environments make up a holistic system comprising individual components that are interrelated and affect each other, therefore affecting the whole. This helps to build a competitive advantage over traditional approaches, which can lead to long-term above-average returns for relevant stakeholders in the system. By using a systemic approach, the changing demand, environmental sustainability and the quality of life of communities can be addressed automatically by satisfying the four main goals of systemic management (Noorani 2009):

1. *System effectiveness* is systems output in terms of its intended benefit, such as sales or export volume, profit, production volume and market share. (Dahl 1994; Hamilton & Chervany 1981; Noorani 2009). Each of these strategies provides a direction for company-level decision making and implicitly develops entry barriers to protect the developed competitive position.

2. *Systems efficiency* is the ratio of systems output to systems input, such as sales volume, sales person and returns on investments (Noorani 2009; Sengupta 1995).

Surviving organisations will be those that are not afraid of changing from a traditional to a systemic approach to cope with change and expand profit opportunities.

3. *Systems health* is the capacity of a system to renew itself with all functioning parts, which is a prerequisite for innovation and growth. Only systemic thinkers will survive in this sector (Noorani 2009).

4. *Systems cohesion* is the capacity of the system to adapt to its changing context, which is a condition for survival (e.g., farmers' turnover, goal of performance). Surviving organisations will be forced to fundamentally restructure their mission, goals and purpose to adapt to systems cohesion (Noorani 2009).

The combination of agricultural industrialisation, trade liberalisation, information technology, decoupled farm programs, environmental concerns and consumer demands for food quality, safety, convenience and nutrition will lead to unprecedented change in the agricultural production and the food and fibre processing and distribution sectors. Successful farm and ranch managers and commodity organisations are likely to be those who develop strategies that allow them to survive and prosper in this changing environment.

This research therefore employs systems thinking tools to access stakeholders' mental models on how to overcome the challenges impeding agricultural and community growth, as well as sustainability, and to measure sustainable development indicators. These principles will serve as guidelines for the whole assessment process, including the choice and design of indicators, their interpretation and communication of the results. They are intended for use in starting and improving the assessment activities of community groups, NGOs, corporations, national governments and international institutions (Hardi & Zdan 1997). This measurement will enable both the industry and policymakers to identify the threats to the sustainability of economic growth and unintended consequences before it is too late to reverse the trend.

6.1.3 Research Approach and Methodology

As mentioned above, systems thinking views a problem as part of the overall system to enhance decision making and problem-solving abilities. This is different to the current and often-used linear approach, which mostly leads to 'quick fixes'. In this study, the ELLab methodology developed by Bosch et al. (2013) is used to bring together researchers from industry and academia, as well as other stakeholders, to deliberate on the challenges and how to overcome them. This approach has been used to deal with complex issues effectively in a variety of contexts (Banson, Nguyen & Bosch 2015a; Banson et al. 2015; Bosch & Nguyen 2014; Bosch et al. 2013; Keegan & Nguyen, 2011; Nguyen & Bosch 2013; Nguyen, Bosch & Maani 2011; Nguyen, Bosch & Nguyen 2014).

The ELLab offers a unique seven-step methodology that provides real-world application of systems thinking for managing complex issues (see Figure 6.1). It aims to introduce systems thinking for scientists, researchers, policymakers, decision makers and practitioners to develop a shared understanding of complex issues and create innovative and sustainable solutions using systems approaches.

Data collection was conducted using the four levels of a thinking model, which consists of four distinct and closely related levels of thinking, as shown in Figure 6.1: events or symptoms, patterns of behaviours, systemic structures and mental models. The figure demonstrates how stakeholders can deal with complex challenges in an unpredictable environment such as agricultural management. This is a unique 'methodology' to integrate collaboratively and use existing and experiential knowledge to help manage complex issues.

Step 1 (gathering mental models) involves establishing an ELLab at the 'fourth level of thinking'. This is the initial step involved in the forum, with experts in the field to gather the mental models of all stakeholders involved in the challenges under deliberation. Their opinions concerning the limitations and challenges behind the complex industry, liberations, implications and potential interventions to overcome challenges supressing agricultural growth and sustainability were discussed during a series of workshops in Ghana. Senge (2006) explains 'mental models as deep-rooted generalizations, or images that influence how we understand the world and how we take action'.

In step 2, capacity-building sessions were held during which the participants learned to integrate the various mental models into a systems structure (Step 3). The Vensim software program (Ventana Systems UK) was used for the development of the CLD using the variables identified through the capturing of the stakeholders' mental models of the issue under consideration.
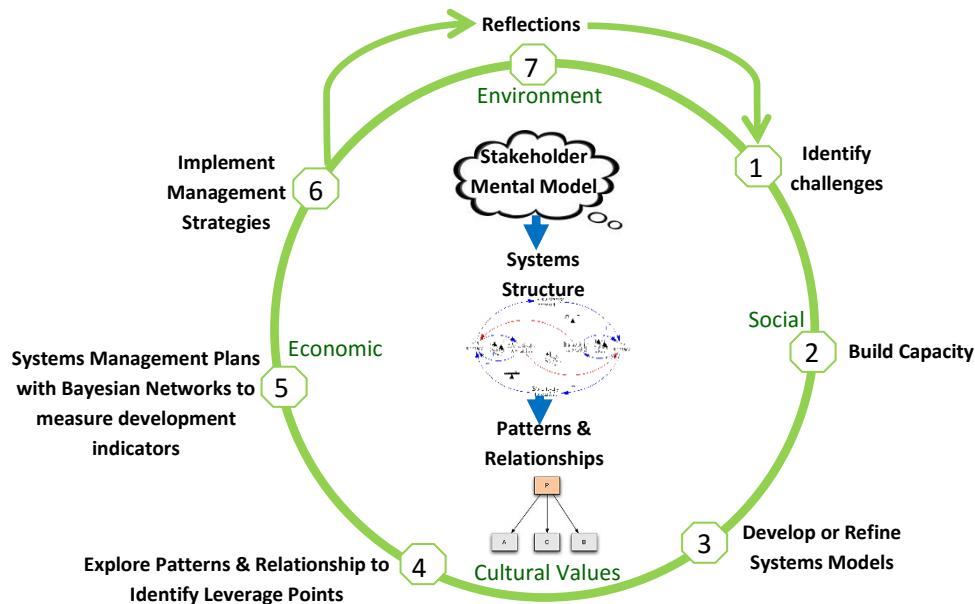
Figure 6.1: ELLab: the basis of the systemic approach for managing complex issues

(Adapted from Bosch et al. 2013)

According to Bosch et al. (2013), this learning approach is of particular importance for all stakeholders that are involved to take 'ownership' of the systems model and outcomes. Once completed, the participants move to Step 4, the 'second level of thinking', by interpreting and exploring the model for patterns, relationships and type of feedback loops that exists. This step aims to assist stakeholders to develop an understanding of their interdependency in solving problems and the role and responsibility of each stakeholder group in the system. Further discussions addressed the main liberations and implications of the system in detail, which provided the stakeholders with a deeper understanding of the implications of coordinated actions, strategies and policies. It also provided the stakeholders with a better understanding of each other's mental models and the development of a shared understanding of the issues under consideration. Interpretation led to the identification of leverage points. As mentioned earlier, leverage points are places within a complex system where a small shift at a point can generate bigger changes in the system as a whole (Nguyen & Bosch 2013).

In Step 5, the outcomes were used to develop a BBN model (Cain, Batchelor & Waughray 1999; Smith, Felderhof & Bosch 2007) that was used to determine the systemic interventions and requirements for implementation and the factors that could affect the expected outcomes or indicators. BBNs are composed of three elements:

1. a set of nodes representing variables of the management system (indicators), each with a finite set of mutually exclusive states (the terms 'nodes' and 'indicators' are used as synonyms throughout this paper)

2. a set of links representing causal relationships between these nodes
3. a set of probabilities, one for each node, specifying the belief that an indicator will be in a particular state given the states of those nodes that affect it directly.

These are called CPTs and are used to express how the relationships between the nodes operate. A CPT thus underlies each node/indicator in the BBN. The CPTs contain entries for every possible combination of the states of the nodes or indicators. Once all the CPTs have been completed, the BBN can be used for analysis. In general terms, this is performed by altering the states of some nodes while observing the effect this has on others. As the model is a network, the effect of changing any variable is transmitted right through the network in accordance with the relationships expressed by the CPTs. Changes in any node simply arise from the combined effect of changes in all the nodes linked to it either directly or indirectly. In formal terms, the BBN encodes a joint probability distribution over all of the nodes. Every time the state of a node changes, the joint distribution is updated through the iterative application of Bayes' theorem (Lunn et al. 2000).

Changes in the BBN are observed as changes in the chance that a node is in a particular state. Due to the uncertainty in the CPTs, it is rare for a node to definitely be in one state or another, and it is far more common for probability distributions across all states of a node to be observed.

The BBN was used because it fulfils the Bellagio principles of measuring sustainable indicators according to Hodge and Hardi (1997), as shown in Table 6.1. Principle 1 deals with the starting point of any assessment—establishing a vision of sustainable development and clear goals that provide a practical definition of that vision in terms that are meaningful for the decision-making unit in question. Principles 2–5 deal with the content of any assessment and the need to merge a sense of the overall system with a practical focus on current priority issues in a holistic perspective. Principles 6–8 deal with key issues of the process of assessment, while Principles 9 and 10 deal with the necessity for establishing a continuing capacity for assessment (Hardi & Zdan 1997).

Table 6.1: Bellagio principles for assessment and the BBN model similarities

	Bellagio principles	BBN
1	Guiding vision and goals Assessment of progress toward sustainable development should: • be guided by a clear vision of sustainable development and goals that define that vision	A software framework to integrate vision and reasoning components that can be compiled and used for analysis by altering the states of some indicators while observing the effect this has on others (Cain, J., Batchelor, C. & Waughray, D. 1999; Henriksen & Barlebo 2008; Henriksen et al. 2007; Lynam et al. 2007; Ponweiser, Vincze & Zillich 2005)
2	Holistic perspective Assessment of progress toward sustainable development should: • include review of the whole system as well as its parts • consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of that state, of their component parts, and the interaction between parts • consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, in monetary and non-monetary terms	The basis of a BN is a diagram conceptualising the environmental system to be managed (Cain, J., Batchelor, C. & Waughray, D. 1999; Molina et al. 2010).
3	Essential elements Assessment of progress toward sustainable development should: •consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over-consumption and poverty, human rights, and access to services, as appropriate • consider the ecological conditions on which life depends • consider economic development and other non-market activities that contribute to human/social well-being	The BN modelling allows account to be taken of systems models to determine the components and interactions between the policy and the social, environmental, economic and other factors (e.g. unstated political considerations) dimensions of the industry (Banson et al. 2015; Cain, Batchelor & Waughray 1999).
4	Adequate scope Assessment of progress toward sustainable development should: • adopt a time horizon long enough to capture both human and ecosystem time scales thus responding to needs of future generations as well as those current to short term decision-making • define the space of study large enough to include not only local but also long-distance effects on people and ecosystems • build on historic and current conditions to anticipate future conditions—where we want to go, where we could go	BN models provide insights into potential system behaviours and leverage points for systemic interventions required for sustainable development over a time horizon long enough to capture both human, ecosystem, political, economic etc. It also helps to anticipate the long-term consequences of their decisions and actions, as well as helps to avoid any unintended consequences of policies and strategies such as 'silo mentality' and 'organisational myopia' (Banson et al. 2015; Nguyen & Bosch 2013).
5	Practical focus Assessment of progress toward sustainable development should be based on: • an explicit set of categories or an organising framework that links vision and goals to indicators	As the BBN is a network, the effect of changing these variables is transmitted right through the network in accordance with the relationships expressed by the conditional probability tables (CPTs) or current indicator value. It consists of a

and assessment criteria
• a limited number of key issues for analysis
• a limited number of indicators or indicator combinations to provide a clearer signal of progress
• standardising measurement wherever possible to permit comparison
•comparing indicator values to targets, reference values, ranges, thresholds, or direction of trends, as appropriate

set of interconnected nodes, where each node represents a variable in the dependence model and the connecting links represent the causal relationships between these variables.
This means that decision makers can balance the desirability of an outcome against the chance that the management option selected may fail to achieve it (Banson et al. 2015; Cain, Batchelor & Waughray 1999).

6 Openness
Assessment of progress toward sustainable development should:
•make the methods and data that are used accessible to all
•make explicit all judgments, assumptions, and uncertainties in data and interpretations

A fully functional BN model recognises stakeholder perspectives by two major activities: 'Stakeholder consultation' and 'Data collection and collation' Data collection may also raise the need for modification of the BN diagram which may, in turn, lead to further stakeholder consultation (Cain, Batchelor & Waughray 1999).

7 **Effective communication**
Assessment of progress toward sustainable development should:
• be designed to address the needs of the audience and set of users
• draw from indicators and other tools that are stimulating and serve to engage decision-makers
•aim, from the outset, for simplicity in structure and use of clear and plain language

The BN address the needs and the 'mental models' of all stakeholders involved concerning the challenges under deliberations through brainstorming to identify appropriate management strategies. This approach takes into consideration support guidance as a way of explaining/translating in the local dialect of the participants where necessary (Banson et al. 2015; Bosch et al. 2013).

8 **Broad participation**
Assessment of progress toward sustainable development should:
• obtain broad representation of key grass-roots, professional, technical and social groups, including youth, women, and indigenous people—to ensure recognition of diverse and changing values
• ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action

The development of a BN model within the ELLab process offers a methodology for creating informal learning spaces or platforms for managing complex issues. It aims to introduce systems thinking for researchers, research managers, decision or policymakers and especially stakeholder groups who are marginalised in decision making but who are, nevertheless, crucial to successful implementation together with women at all levels to develop a shared understanding of complex issues and to create innovative and sustainable solutions using systems approaches (Banson, Nguyen & Bosch 2014; Bosch et al. 2013).

9 **Ongoing assessment**
Assessment of progress toward sustainable development should:
• develop a capacity for repeated measurement to determine trends
• be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently
• adjust goals, frameworks, and indicators as new insights are gained
• promote development of collective learning and feedback to decision-making

Parts of a BN developed for one decision problem (including the information used to drive it) might well be useful in a later BN developed for another problem. In the long run, stakeholders take ownership of the solution which ensures adoption and implementation because it is their own mental model (Banson, Nguyen & Bosch 2014; Bosch et al. 2007; Bosch et al. 2013; Cain, Batchelor & Waughray 1999).

10 **Institutional capacity**
Continuity of assessing progress toward sustainable

The BN model is used as a simulation model to

development should be assured by: • clearly assigning responsibility and providing ongoing support in the decision-making process • providing institutional capacity for data collection, maintenance, and documentation • supporting development of local assessment capacity	test the possible outcomes of different systemic interventions by observing what would happen to the complex system as a whole when a particular strategy or combination of strategies are implemented: that is, before any time or money is invested in actual implementation. The BN helps decision makers anticipate the long-term consequences of their decisions and actions, as well as help avoid the danger of 'shifting the problems' or 'giving rise to bigger problems to fix later' (Banson et al. 2013; Bosch et al. 2013).

The BBN model was used to identify systemic interventions through rapid sensitivity analysis (identifying those factors that had the biggest effect on the goal [achieving the leverage point]) that were subsequently used to develop an integrated master plan with orderly defined goals (leverage points), strategies (systemic interventions) and indicators to measure success in the next step of the ELLab (implementation).

Indicators were suggested by the stakeholders during these workshops based on how well they could address the issue of the community's carrying capacity relative to community capital—natural, human and social resources—that is, not at the expense of global sustainability (Hart, Hart & Angelo 2014). According to Hart, Hart and Angelo (2014), an indicator helps one to understand how well a system is working by pointing to an issue or condition.

This study focuses on the first five steps of the ELLab, but they form part of the seven-step process because they will be embedded in the co-learning cycle of the ELLab. Step 6 will include the implementation of the strategies and/or policies that will create the biggest effect by the managers or policymakers. Targets will be determined and monitoring programs will be implemented to measure and/or observe the outcomes of the strategies and policies.

Step 7 is an important part of the ELLab process, as no systems model can ever be completely 'correct' in a complex and uncertain world. The only way to manage complexity is by regularly reflecting on the outcomes of the implementation phase. Successes and failures are then used to identify unintended consequences and to determine, through co-learning, how to adapt the strategies that do not result in the desired outcomes (Bosch et al. 2013).

6.2 Results and Discussions

6.2.1 Causal Loop Diagram and the 'Big Push' Model

The data in a form of mental models collected from all the workshops and discussions (Step 1 of the ELLab) were integrated into a CLD with the help of the researchers, as illustrated in Figure 6.2 (Step 3). This reveals the causal relationships among a set of variables (or factors)

influencing competitive development within the agricultural systems. The CLD in Figure 6.2 explains the sources of complexity that has given rise to poor sustainable economic development within Ghana's agricultural communities.
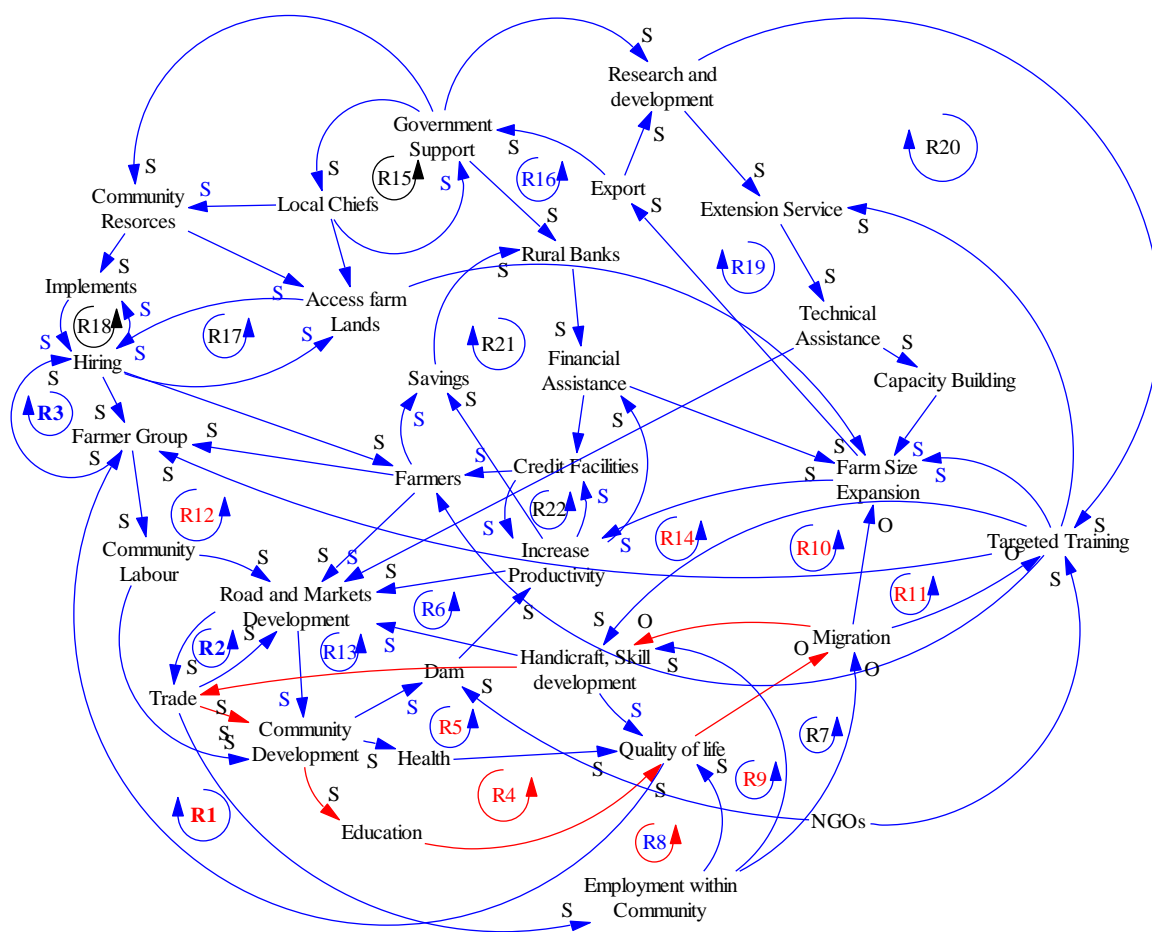
Figure 6.2: Competitive development model

From the CLD, it is apparent that the relationships between the key variables are far from simple or linear. The CLD further demonstrates the influence of qualitative variables such as 'government support' in a form of policy and provision of agro-equipment and its chain effects on other key outcomes. An inspection of this CLD reveals that the current undesirable outcomes (poor quality of life, poor to zero infrastructures, unemployment, migration and unsustainable community development) can be traced back to the lack of community resources, leading to poor wellbeing of communities. An unintended consequence of this is that agricultural productivity diminishes, food prices increase and poor victims rely on forest covers (charcoal burning, hunting, firewood), which in turn affects river flow and the ecosystem. Having identified the root causes of the complex problems, the appropriate intervention strategy can be devised. In the case of Ghana's agricultural communities, the leverage lies in integrated planning and coordinated government policies. The effects of these strategies are shown in Figure 6.2. As shown, these strategies create 22 positive reinforcing 'loops' (shown by the 'R' sign). These loops represent the reciprocal and beneficial effects of

government support in resources and the chain effect of these on the sustainability and livelihood of the communes.

With inequality rising almost everywhere in Africa, including Ghana, governments and community leaders need to urgently expand and improve their public investments in inclusive growth. This approach will catapult counter-dependent and dependent resource-poor farmers or stakeholders to independent and interdependent relationships, which is the ethics for systems sustainability (Noorani 2009).

Stakeholders proposed modern agriculture to include innovation in agricultural machinery and farming methods, genetic technology, techniques for achieving economies of scale in production, the creation of new markets for consumption, the application of patent protection to genetic information, and international trade.

Figure 6.2 illustrates how the economy can be leveraged to greater productivity and at the same time industrialising while improving the quality of life, as proposed by the 'big push' model (Rosenstein-Rodan 1957). Government support in the form of the provision of implements and an alliance with local chiefs to demarcate agricultural lands will initiate community development and system cohesion.

The 'big push' model (see Figure 6.3) is a concept in development economics or welfare economics that emphasises that a company's decision of whether to industrialise depends on its expectation of what other companies will do (Murphy, Shleifer & Vishny 1988). It assumes economies of scale and an oligopolistic market structure and explains when industrialisation will occur. The 'big push' model emphasises that underdeveloped countries require large amounts of investments to embark on the path of economic development from their present state of backwardness (Todaro & Smith 2009).
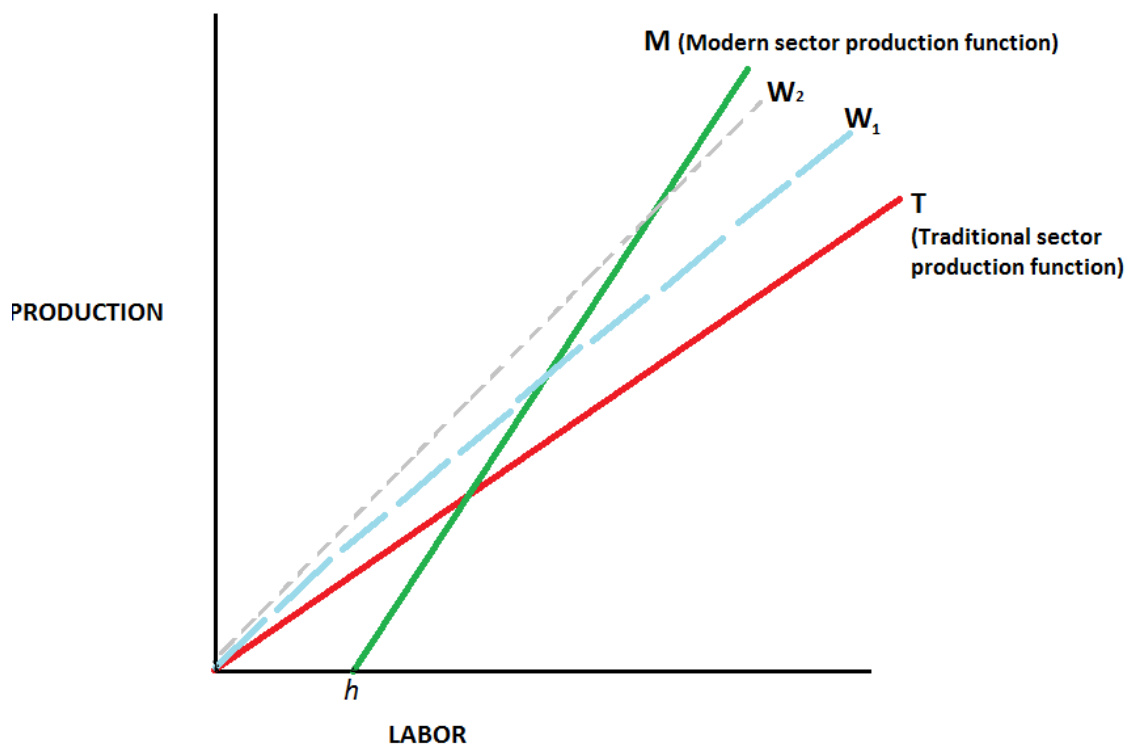
Figure 6.3: 'Big push' model

Source: (Todaro & Smith 2009)

This theory proposes that a 'bit-by-bit' investment program will not affect the process of growth as much as is required for developing countries. It stipulates that injections of small quantities of investments will merely lead to wastage of resources. Paul Rosenstein-Rodan, approvingly quotes a Massachusetts Institute of Technology study in this regard, a minimum level of resources must be devoted to a development program if it is to have any chance of success. Launching a country into self-sustaining growth is similar to getting an airplane off the ground. There is a critical ground speed that must be passed before the craft can become airborne (Rosenstein-Rodan 1957). Stakeholders proposed that if governments can support them by providing a minimum level of resources in the form of agricultural machinery, such as tractors, harvesters and caterpillars, it will give them hope and a chance of success, which can catapult them to self-sustaining growth. They proposed that they can hire this equipment at a subsidised rate to pave their own community roads and develop their own community markets through cooperative or individual groups, depending on availability. According to Rosenstein-Rodan (1957), when a group of stakeholders plan together according to their social marginal products, the rate of growth of the economy is greater than it would have otherwise been. Stakeholders ascertained that with this and other developments within the community, such as schools, hospitals and dam development, improved performance and quality of life of its members will be triggered, as shown in Figure 6.2.

It was also ascertained that with the developed community market, trade can increase to promote handicraft and skill marketing, thereby reducing out-migration and promoting system health. This will in turn promote the development of rural banks and increase farmers' savings and credit worthiness. With financial and technical assistance from the rural banks and extension services, capacity will be ensued and farms sizes and productivity will increase leading to more trade (sales volumes, returns on investment etc.) and employment within the community to facilitate systems efficiency. These will boost systems output in terms of its intended benefits such as high sales volume, profit, production volumes and market share expansion leading to export as shown in Figure 6.2.

The 'big push' has many drawbacks (Easterly 2006; Guillaumont & Guillaumont Jeanneney 2007; Todaro, MP & Smith 2009). Guillaumont and Guillaumont Jeanneney (2007) argue that, there is a probability that a poverty trap exists for many developing countries and that an increase in aid is relevant for them. However, they proposed that the decrease in marginal aid returns is slower in vulnerable countries, which supports the rationale to include vulnerability as one of the aid-allocation criteria. The main obstacles to absorptive capacity, such as disbursement constraints and short-term bottlenecks, macroeconomic problems, including loss in competitiveness and macroeconomic volatility, as well as the weakening of institutions are not factored by the 'big push'. The 'big push' recommendation overlooks the unsolvable information and incentive problems facing any large-scale planning exercise (Easterly 2006). It also assumes that, small investments do not have affect the whole which contradicts systemic principles—thus this paper has come up with a new model from a systemic point of view called, the 'greater push model' as shown in Figure 6.4.

6.2.2 Systemic Development—The 'Greater Push' Model

As in the case of Ghana, African economy is characterised by a large number of sectors that are interrelated to the extent that any effect on productivity of one sector affects the whole system. Each sector can either rely on traditional approaches or switch to a systemic approach to deal with challenges which would affect its efficiency. With the following two assumptions in mind:

1. There are l investments to be made in n sectors, each sector will have l/n investment (Lange 1960; Todaro & Smith 2003);
2. The traditional approach only deals or treats the symptoms of the challenges, while systemic approach deals with the root cause of the challenges (Banson, Nguyen & Bosch 2014; Bosch et al. 2007; Bosch et al. 2013);

Then when using a *traditional approach*, a sector would produce l/n amount of output, which may result in further consequences such as shifting the problem to other sectors with each investment producing less than one unit output or even negative. However, when using a *systems thinking approach,* a sector would produce much more, because the productivity would be greater than one unit per investment through leverage points with positive cascading affecting the other sectors.

In Figure 6.4, the x-axis represents the investment employed and the y-axis represents the level of productivity.
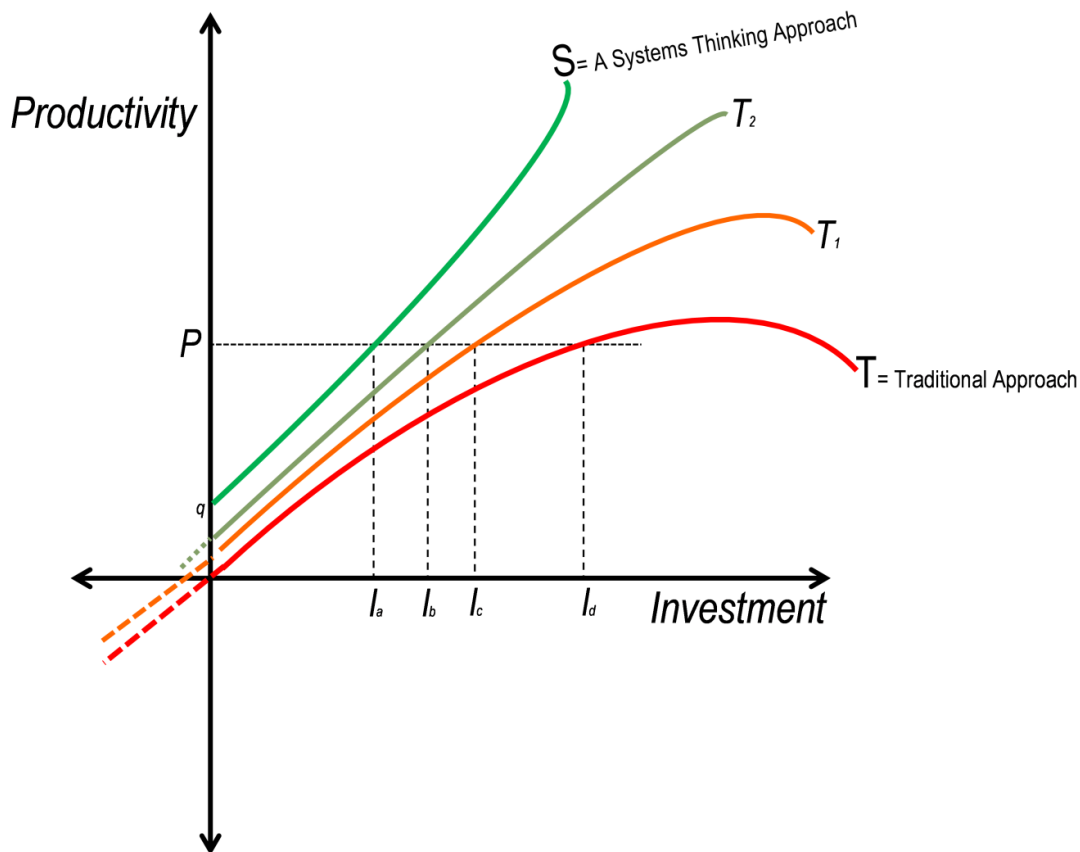
Figure 6.4: 'Greater Push' model. Adapted from the 'Big Push' model

The productivity as a result of using the traditional approach in the sectors is given by the curve 'T' and the productivity using the systems thinking approach in the sectors is given by 'S'. The curve 'S' has a positive intercept on the y-axis, implying that there are self-organisation cascading positive effect of growth and sustainability of the whole system (Heylighen 2001).

Therefore with the assumption of l/n investment in the economy, the systemic approach will have a higher level of productivity than the traditional approach. The production function as a result of the systems thinking approach is steeper than that of the traditional approach as a result of dealing with the root causes of challenges, thus the higher productivity of investment

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in the former. The slope of both production functions is $1/S$, where 'S' is the marginal investment required to produce more than one additional unit of output. This level of 'S' is lower using the systemic approach than it is for the traditional one.

Assume that a *traditional approach* was used to address a particular challenge in the sectors using one unit of investment; then the output generated in the whole system is

$$Output = \frac{1}{n} - Z^{\{1+x\}}.$$ We have two possible cases: a fix 'now' shifting the problem to other sector or giving rise to a much bigger problem to fix 'later' thus $Z^{\{1+x\}}$ is the diminishing factor as a result of organisational myopia with $\{1+x\}$ as the compounding rate at which the problem is cascading in the whole system (Luehrman 1998).

However, using the *systems thinking approach*, output generated in the whole system will be

$$Output = \frac{1}{n} \times Z^{\{1+x\}}$$

Thus productivity 'P' increases as an economy shift from the traditional to a systemic approach. The BBN model in the next section provides ways to measure sustainable indicators and to ascertain how well a community is meeting the needs and expectations of its present and future stakeholders.

6.2.3 Indicators for Sustainability

Sustainability requires that the wellbeing of community—the combination of community liveability, environmental sustainability and economic prosperity—is maintained or improved over time (Department of the Environment 2013). Measuring sustainability is about monitoring how each indicator performs over time. A good indicator alerts one to a problem before it gets worse and helps to recognise what needs to be done to address the problem. Indicators of a sustainable community point to areas where the links between the economy, environment and society are weak. Indicators of sustainability are different from traditional indicators of economic, social, and environmental progress. Traditional indicators such as stakeholder profits, interest rates, and quality of life—measure changes in one part of a community as if they were entirely independent of the other parts. For all workshops and interviews during the study, indicator selection generated discussion among people with different backgrounds and viewpoints, and, in the process, helped to create a shared vision of what the indicators should be. Using the Netica software package (Norsys Software Corp 2014), the indicators were constructed into a simulation model in which the original plan (or baseline) are identified and managed to keep the project within scope, on time, and within budget as shown in the Figure 6.5. Saving a baseline plan enables the identification and

solving of discrepancies and planning more accurately for similar future projects. The sustainability indicators have been designed to reflect both stocks (quantity and quality of resources) and flows (uses or drivers of change in stocks) of social and human, natural and economic capital. Sustainability indicators reflect the reality that the different segments are intrinsically interconnected. In contrast, a comparable sustainability indicator is the Index of Sustainable Economic Welfare.
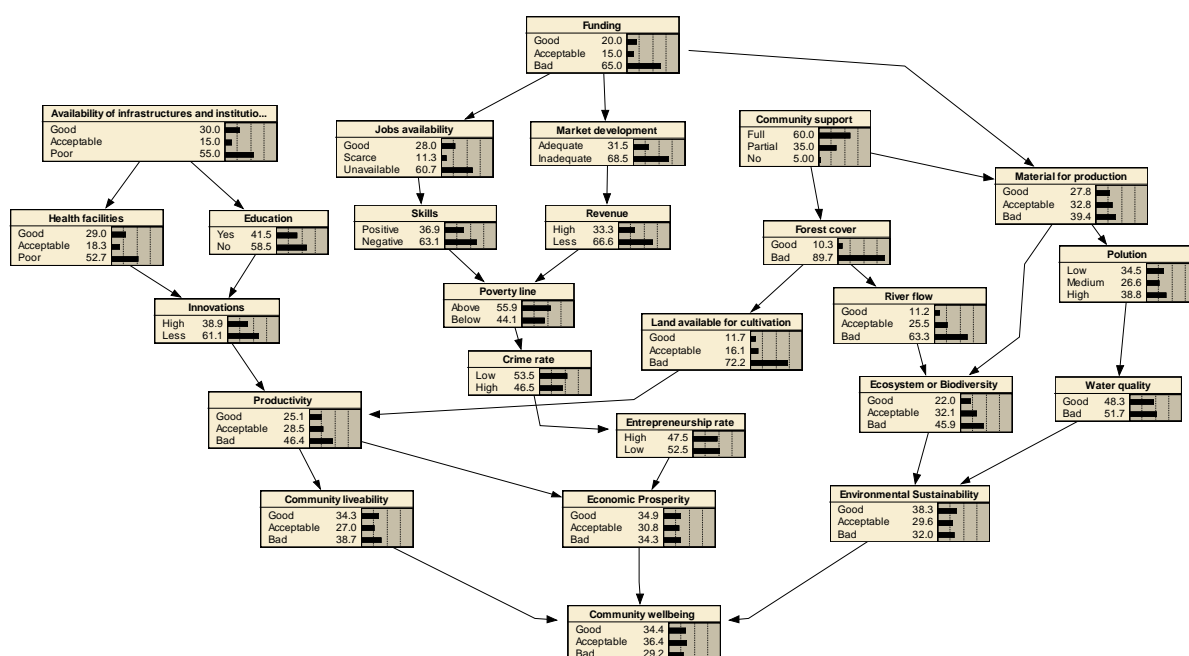
Figure 6.5: Bayesian Belief Network showing the current agricultural development indicator system affecting community wellbeing in Ghana

As Figure 6.5 illustrates, the natural resource base provides the materials for production upon which jobs and stakeholder profits depend. The structure of this diagram encodes the perception that revenue is affected by market development and this, in turn, affects the income and investment rate (entrepreneurship) which determines economic prosperity and the entire wellbeing of the community. Also river flow is affected by forest cover (10.2% of land area) (Koranteng & Zawiła-Niedźwiecki 2008) and this, in turn, affects the ecosystems and bio-diversities on which the entire wellbeing of the community depends. Other relationships represented by the diagram can be obtained from the BBN in a similar way. Jobs affect the poverty rate and the poverty rate is related to crime. The development of social capital with available infrastructures and institutions has a positive effect on innovations through the provision of health care and education, which affects community productivity and liveability. Economic prosperity encodes the perception that, market development affects revenue, which in turn affects poverty, crime rate and entrepreneurship development. They may also affect stockholder profits.

Sustainability requires this type of integrated view of the world since it requires multidimensional indicators that show the links among a community's economy, environment, and society. For example, the Gross Domestic Product (GDP), a well-publicised traditional indicator, measures the amount of money being spent in a country. It is generally reported as a measure of the country's economic well-being: the more money being spent, the higher the GDP and the better the overall economic well-being is assumed. However, because GDP reflects only the amount of economic activity, regardless of the effect of that activity on the community's social and environmental health, GDP can go up when overall community health goes down. For example, when there is a ten-car pileup on the highway, the GDP goes up because of the money spent on medical fees and repair costs. On the other hand, if ten people decide not to buy cars and instead walk to work, their health and wealth may increase but the GDP goes down.

6.2.4 Monitoring and Evaluations

The BBN in Figure 6.5 was used as a simulation model to monitor, measure and evaluate the possible outcomes of different sustainable development indicators by observing what would happen to the system as a whole when a particular strategy or combination of strategies was implemented to alter its indicator. If community wellbeing is within an acceptable level (see Figure 6.5), then we would expect significant positive effects on the rest of the indictors within the network. With this information, the intervention can be adapted to encourage positive feedbacks.

For example, in Figure 6.5, the probability for forest cover is 10.3%. It is evident from the discussion above that improving farmers' market development, forest cover, and ensuring infrastructure availability are key leverage points for ensuring community wellbeing and sustainable agriculture. These interventions will have a positive effect on the other indicators.

The BBN model (see Figure 6.5) indicates that the probability of the current level of revenue is 33.3%, the percentage of Ghanaian population living below the international poverty line $1.25 (in purchasing power parity terms) a day is 44.1 (Olinto et al. 2013; UNDP 2012a) with the probability of community prosperity as 34.9%. Developing market as intervention strategies, revenue increased from a probability of 33.3% to 95%, farmers below the poverty line reduced from 44.1% to 7.93% (see Figure 6.6) and the probability of the prosperity of the community increased from 34.9% to 46.8%.

The expected outcomes are presented in Figure 6.6. This simulation provides added opportunity to test possible strategies that can affect any indicator before any time or money is invested in actual implementation.
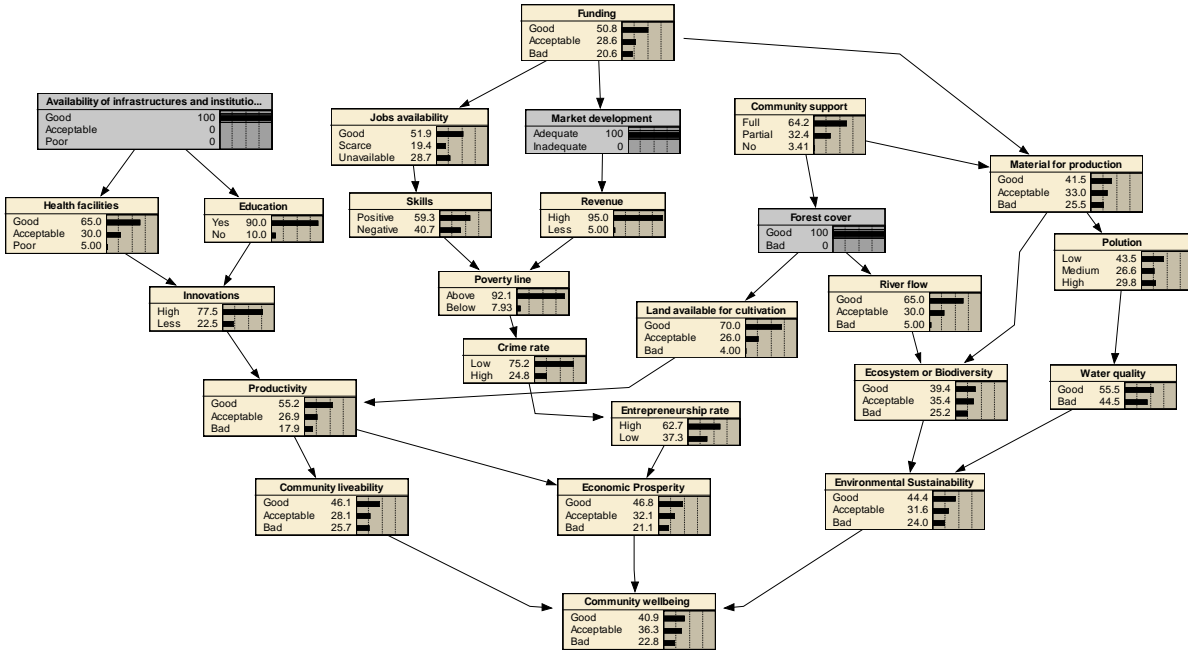
Figure 6.6: Bayesian network showing the agricultural development indicator system related to community wellbeing in Ghana

(With intervention: market development, infrastructural development and improving forest cover)

As a result of altering forest cover as a systemic intervention (see Figure 6.6), a ripple effect is amplified on the other indicators, such as river flow, ecosystem/biodiversity and environmental sustainability, thereby altering their state. This has been graphically presented (see Figure 6.7) using percentage change tabulations (Equation 1) to calculate the state of the indicator (x) while varying percentage change (y) and depending on the project scope, time, and budget, growth rate of each indicator can be tabulated using Figure 6.7.

$$x = \left(\frac{y}{100}\right) \times CurrentValue \quad + CurrentValue$$

(1)

Where *x* is the state of the indicator at a percentage-change *y*.

Figure 6.7 indicates that when forest cover is improved at a time *t*, it will cause ripple positive effect on river flow improving the ecosystem or biodiversity to enhance environmental sustainability to affect community wellbeing.

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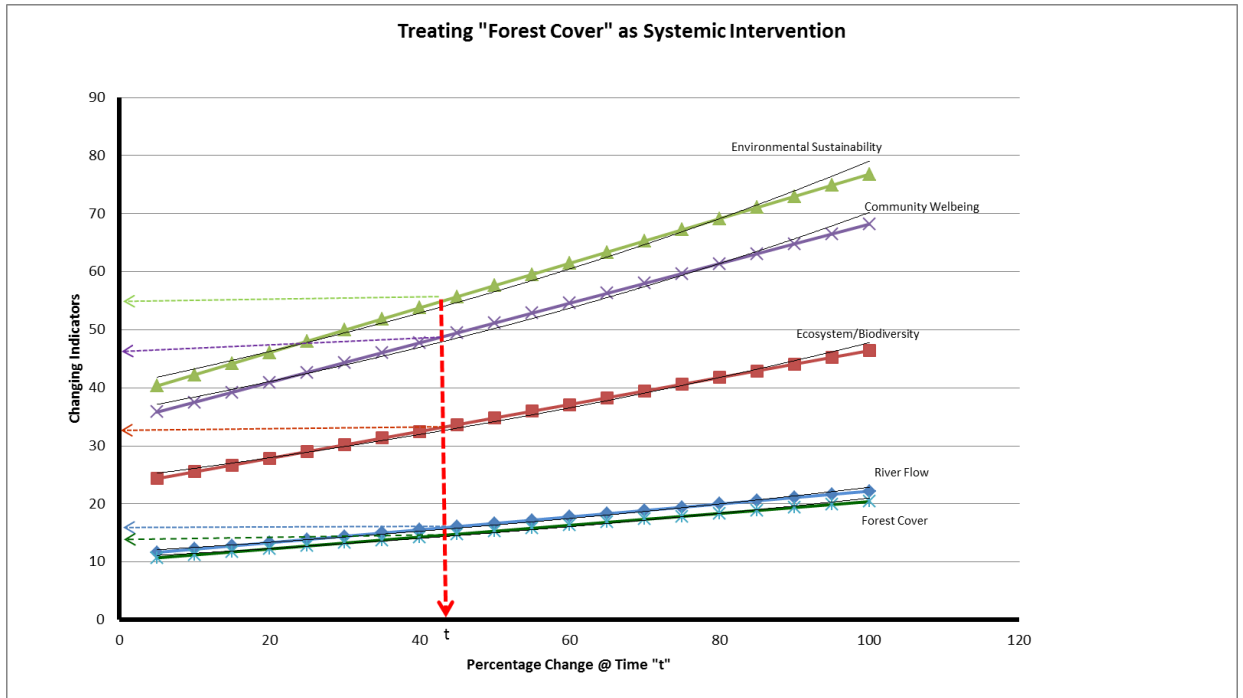
Figure 6.7: Graphical presentation of the effect of improving forest cover as systemic intervention

These indicators can be tabulated as a proportion of their actual SI units to get the measure of their value. For example, according to (FAO 2002), forest and wildlife reserves occupy 18,000 km^2 or 22% (see Figure 6.5) of the forest zone of Ghana. In order to measure the effect of improving forest cover as a systemic intervention, it can be deduced from Figure 6.7 as a percentage change on forest and wildlife reserves at time t, as expressed below.

$$x = \left(\left(\frac{45}{100}\right) \times 18,000\right) + 18,000 = 26,100 km^2$$

Meaning with systemic intervention to improve forest cover at period t will increase forest and wildlife reserves by 8,100km^2.

6.3 Conclusion

We live in an interdependent world where social, environments, political and economic problems soon collide, and therefore systemic approaches and networks of cooperation to deal with complex issues will be the dominant mode of success to catalyse effective investment to protect global commons and increase resilience. Only by applying systemic knowledge can we sustain our communities and derive benefit from an increasingly complex future. This paper has demonstrated how a systemic approach as a management tool can be applied to agricultural development to increase it competiveness. Systems thinking gives rise to a new art of thinking required in business, management and finance as well the technical aspects of managing economic development for the 'greater push' effects. The 'greater push model'

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assumes holistic thinking and interrelationships to the extent that any small effect of productivity on one sector affects the whole system, as proposed otherwise by the adapted 'big push' model. It has also shown that u*sing a systems thinking approach,* a sector's productivity would be much higher per investment through leverage points with positive cascading effects on the other sectors compared to the traditional approach. This can complement the 'big push' model as a concept in development economics or welfare economics should a nation require to increase productivity and economic development in this complex world.

The CLD in Figure 6.2 has revealed the sources of complexity that has given rise to the poor sustainable economic development within Ghana's agricultural communities, with increasing changes in both size and complexity. From the analysis, the BBN for measuring sustainable indicators fulfil the Bellagio Principles. This research has ascertained that agricultural competitive and sustainable development indicators in Africa can be monitored, measured and evaluated in the phase of complex challenges, and exacerbates threats to biodiversity and sustainability. The BBN has an advantage to both pre and post-test indicators through simulation of the baseline plan for possible outcomes of different systemic interventions before any time or money is invested in actual implementation to keep the project within scope, on time, and within budget. With the BBN for sustainable indicator measurement and evaluation, the management process can become less difficult in planning, analysis, and control-skills aimed at guiding the future course of organisations faced with accelerating rates of evolution in technical, social, political, and economic forces. Further, with the BBN as a cutting-edge analysis, one can assess the implications and trade-offs of alternative land-use and development scenarios that reflect key socioeconomic and environmental priorities. Based on the above analyses, it is evident that the models can be used as decision-support systems where one can learn and adapt more effectively than in other approaches, which do not use systemically determined decisions for adaptive management. This support tools will help African policymakers reconcile their objectives and decisions to enhance sustainable development. It is clear that there need to be a focus on cutting-edge systemic technologies and state-of-the-art developments to guide decision and policymakers to solutions in this challenging complex world.

Chapter 7: Conclusions and Recommendations

This chapter provides the overall conclusions and suggests further research directions. The research entitled "a systems thinking approach to address the complexity of agribusiness for sustainable development in Africa: a case study in Ghana" was conducted by formulating and addressing five research questions (RQs). As demonstrated in sequence, each of the five papers (Chapter 2 – Chapter 6) has discussed in detail and presented the answers to each of the research questions. Briefly as follow:

RQ 1: What are the pressing constraints and challenges to agricultural systems' management and enactment of agricultural policy? The important outcomes addressing this research question include the establishment of CLDs of the various web/interconnected components of the agricultural industry in Africa. These diagrams/models demonstrate the high level of complexity and therefore many challenges that are facing stakeholders and the performance of the agricultural industry. The models also reveal the interactions between the policy, the social, environmental and economic dimensions of the industry, giving insights into potential systems behaviours and leverage points for systemic interventions that would be required for sustainable agricultural development. The findings also show that, the lack of integrated strategic management plans in the governance structure has led to disjointed government policies with unintended negative consequences, coupled with a lack of unity in fixing challenges among international agencies. These unintended consequences also lead to unsteady demand and poor agribusiness sustainability, creating a vicious cycle.

RQ 2: What are the interaction of the structure, conduct and performance (SCP) of the agricultural sector? This was addressed by revealing how the SCP elements interact together to influence the survival and growth of the agricultural sector. This in turn influences production and allocative efficiency of resources for improving food security, the ecosystem and the strengthening of agricultural sustainability. The respective CLD and BBN models reveal that, the ability of Ghana to sustain its food security and natural resources management is subject to many interacting factors. These are not only limited to economy, environment, and socio-demography but include diverse stakeholders with varied different objectives and agendas adapted for survival. Both models in research question one and two were used as "simulation models" to develop and test alternative management policies.

RQ3: What are the opinions of stakeholders concerning how the agricultural system works, the barriers to success and the system drivers? System archetypes serve as valuable diagnostic tools helping to anticipate potential drivers and barriers for sustainable agriculture in Africa, which also help to gain better insights into the underlying systems structures from which the archetypal behaviours emerge. The behaviour over time graph and established

models reveal that as the African population increases, people explore new agricultural land that is in direct conflict with the conservation of forested areas, hence leading to environmental degradation. These challenges, in addition to the depletion of natural resources, have worsened the plights of African farmers. A new systems archetype called "success to damage" archetype has been discovered in the Ghanaian agricultural industry that could help African agricultural proponents to increase productivity and induce investment in the agricultural sectors. The study shows that opportunity and risk matrix as a policy tool does not solve the problems, but complimenting this approach with a systemic approach would lead to the provision of sound management strategies and policies.

RQ 4: What are the possible new strategies or solutions that need to be designed to overcome these challenges or problems in the agricultural sector? Results show that, the last 10 years have brought numerous and encouraging modernization efforts to improve the agricultural sector in Africa and Ghana. However, agricultural production and productivity continue to decline as a result of the dependency on traditional approaches. The developed systems model helps to prioritise actions and understand the importance of addressing the core issues rather than symptoms; creating a collaborative platform for integrated sustainable resource management in the agricultural industry, which can be duplicated by other agrarian economies around the world. Results show that capacity building is an important systemic interventions to address the challenges in African agriculture. It has a remarkable impact on the ability of the agriculture industry to evolve, improve and raise in its efficacy and productivity, reducing poverty among farmers and raising their quality of life.

RQ 5: How can competitiveness be increased through the formulation of management policies that will help in the proper allocation of a country's scarce resources? The findings reveal that, the 'greater push model' can serve as a way for agrarian nations to induce growth and sustainability in Africa. The established community development model could serve as a guide to overcome the plight of farming communities and also induce economic development and urbanisation. The model further provides an alternative way for measuring, monitoring and evaluating sustainable development indicators through the use of BBN modelling, which satisfies the 'Bellagio principles' for measuring sustainable development. Nations of the world are interdependent where social, environments, political and economic problems collide, and therefore systemic approaches and networks of cooperation to deal with complex issues will be the dominant mode of success to catalyse effective investment for protecting global commons and increasing resilience.

In addition, the study and its employed systems approaches and tools could serve as useful information and tools for African governments to analyse the performance of policies that are

affecting the agricultural sectors. The approaches and models can also help governments and policy-makers across the world to identify threats to sustainable economic growth and help them to anticipate some unintended consequences of their decisions and actions before it is too late for the trend to be reversed.

Systemic approaches significantly could help agriculture to remain the engine that develops and empowers emerging and existing commercial agribusiness sectors and entrepreneurs across Africa. This research has demonstrated the use of systems thinking tools such as CLDs, BBN, behaviour over time and systems archetypes using the ELLab framework to reveal insights into the complex agricultural structure to induce adaptive sustainable management. Together with stakeholder involvement, a systems approach to identify the root causes of challenges and leverage points for systemic interventions for adaptive sustainable management have the particular advantage of assisting the integration of corporate knowledge. The process of systems mapping provides a framework in which stakeholders can share their understanding of systemic interventions and their dependency relationships. This creates a co-learning environment that facilitates communication among managers, scientists, farmers and policymakers, and it identifies a diverse range of interventions that affect planning, implementation, monitoring and reviewing of key agricultural sustainable management objectives.

The abstract models developed within the ELLab framework during the workshop processes can be used to assess current operational performance with respect to planning, implementing, monitoring and reviewing objectives and their success factors. The approach also provides a means for conducting sensitivity and scenario analyses that highlight significant unintended consequences in the operating industry and test alternative management policies before any time or money is invested in implementation to keep the project within scope, on time and within budget. This will significantly help in the proper allocation of a country's scarce resources, unlike traditional performance indicators, which do not allow for dynamic scenario analysis. This will help to eliminate or minimise the waste of scarce resources and significant unintended consequences associated with funding R&D. This research has clearly ascertained that agricultural competitive and sustainable development indicators in Africa can be monitored, measured and evaluated in under conditions of complex challenges and exacerbated threats to biodiversity and sustainability.

BBNs were used to build abstract models. The case study highlights a number of benefits of using BBNs in system modelling. First, they provide a way to diagrammatically capture the systemic interventions influencing objectives and their dependency relationships, as described by stakeholders. Second, they provide a way to integrate a diverse range of interventions (e.g.,

equipment, extension services, access to data and information, policies) and quantify their relationships. Third, they allow for dealing with variability and uncertainty in these relationships to be accommodated through the use of the CPTs to populate the models. Fourth, they can be used as a tool to identify poor performance areas, assess the relative influence of poor performance areas on objectives through sensitivity analysis and test the expected effects of improving performance in the agricultural industry. Another advantage of BBN modelling is that ongoing monitoring and survey results can be used to update models over time. This allows for a periodic assessment of performance and an evaluation of the efficacy of interventions targeted at eliminating the root causes and stumbling blocks to adaptive sustainable management.

The limitations associated with complex BBNs (large probability tables and dilution of the influence) meant that the range of critical interventions believed to influence the objectives often had to be summarised into a few nodes, with as few states, as possible. This meant that all factors mentioned by stakeholders could not be captured in the models (at least not in the form or words they have given during the data gathering process).

Capacity-building and governance using a systems thinking approach and the ELLab framework in business decision-making processes and policy analysis has been proven to be effective in understanding complex design problems. Systems thinking gives rise to a new art of thinking required in business, management and finance, as well the technical aspects of managing economic development for the 'greater push' effects. Application of these models in Africa and Ghana can complement other traditional tools to help policymakers and managers understand the behaviour of the entire complex systems and will provide more clarity of consistency in policy objectives. As prospective tools, system archetypes will alert governments to future significant unintended consequences based on policies intended to be implemented.

Key leverage points can also serve as intervention points within the agricultural system for governments and policymakers at other development agencies such as the World Bank, FAO and NGOs, and will ensure effective policies for sustainability. We need to move past the information stage to revelation knowledge for Africa and the rest of the world in order to solve the complex challenges that result in famine, pests, war and terrorism,. For African governments to make the right management decisions in the face of a continually changing political and socioeconomic landscape, they must ensure that policy documents pass a systemic test to prevent failure in the long run. The root causes of African challenges are easy to identify; however, for many decision makers and policymakers, they are completely hidden. To resolve today's challenges, decision makers and policymakers must go beyond

traditional approaches in addressing challenges, to systems perspectives that address the root causes rather than the symptoms. Systems thinking offers a range of analytic tools to improve our capacity to think systemically, including ways to distinguish problem symptoms from root causes. However, in an emergence situation, quick fixes can be used to address the problem systems in the short run before leverage points are identified to deal with the problem's root causes.

Overall, the research approaches used in this study are adaptable and can be applied to address complex challenges facing the performance of agricultural development - not only in Africa, but also in agricultural communities around the world. The ELLab offers a methodology for creating informal learning platforms for managing complex issues and ensures that stakeholders take ownership of the solution, because it is their own mental model and, in the long run, it ensures adoption and implementation. Example can be seen at the CatBa Biosphere reserve in Vietnam as stakeholders have taken ownership to preserve the biosphere because of the ELLab application.

A final conclusion that can be drawn from this research is that the process used to build the models of the adaptive sustainable management intervention is just as important as the models themselves. If the process that was used is inclusive of stakeholders and their knowledge, and the tools are comprehensible, there will be a greater chance that the outcomes of the systems analysis will be adopted and implemented. In the long term, the capacity and implementation of systemically determined interventions, policies and strategies could result in a high chance that the agricultural industry will evolve, improve and raise its efficacy not only in Ghana, but also in Africa and the rest of the world. This would also lead to a significant increase in the yields and profits of farmers and actors and subsequently to an improvement of the quality of life of the African peoples. Future research on the application of systems thinking and system dynamics in the African complex governance systems is recommended to identify the root causes of corruption. This is clearly of great importance to decrease state losses (e.g. state tax income) and to improve the economic activities and quality of life of its peoples.

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