Lilli Scheiterle

The role of institutions and networks in developing the bioeconomy: Case studies from Ghana and Brazil

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Co-Reviewer:	Prof. Dr. Donato Romano
Third Examiner:	Prof. Dr. Claudia Bieling
Head of committee:	Prof. Dr. Jörg Bennewitz

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Executive summary

An increasing number of countries have begun putting focus on developing a bioeconomy strategy. The bioeconomy provides a new concept with the aim to design a sustainable economy, which is knowledge-based and based on the use of biological resources. This entails on the one hand higher production of biomass and on the other tighter networks of traditional, national and international institutions. Institutional networks are pivotal for the sustainable production and use of biological resources, as well for the development of innovative biological processes and principles to exploit the potential of biomass. This thesis explores three pivotal aspects needed to take advantage of the considerable untapped potential of the bioeconomy. The first case study aims to identify the determinants of the persisting low maize yields in northern Ghana, despite the introduction of a fertilizer subsidy program. The policy is largely regarded as an instrument to increase crop productivity and contribute to food security. The second empirical study explores the role of female-led market institutions in Ghana. Marketing is central to the development of the bioeconomy and as such, trader organizations have a key role to play the value chain. The third case study investigates, taking sugarcane as a case study example, how well Brazil, the world's leader in sugarcane production, is positioned to realize the shift from a fossil-based to a bio-based economy (bioeconomy).

The two case study countries Ghana and Brazil were chosen because of their comparable net primary productivity and pedo-climatic conditions, and because of their different stages in the realization of the bioeconomy. Two components are pivotal to the success of the bioeconomy: biomass and knowledge. Based on two case studies in Ghana, this thesis investigates first the efforts to increase maize productivity in the Guinea savanna and secondly explores the role of collective action groups as central actors to address the sustainability dimension of the bioeconomy. Brazil has successfully implemented pivotal aspects of the bioeconomy, especially in the sugarcane sector. For this reason it lends itself well to analyze the role of institutions and networks in the development of new processes and products.

This study adopts a mixed methods approach to address three key aspects of the development of the bioeconomy: production, marketing, and the overall innovation system. Data collection and analysis included qualitative and quantitative methods from various disciplines. The findings are presented in three papers, which this cumulative thesis is composed of.

The first paper adopts a multidisciplinary approach. A household survey, in-depth interviews, and focus group discussions served to gather data on the socio-economic challenges of maize production in the Guinea savanna. Additionally, soil and fertilizer samples were analyzed to identify natural constraints and potential governance challenges. The results from this paper show that both socio-economic and biophysical parameters contribute to an improved understanding of site-specific challenges, resulting in low maize productivity in the Guinea savanna of Ghana.

The second paper explores the role of female-led market associations across regions, ethnicities, and market typologies throughout Ghana. For this study a qualitative approach was chosen with participant observation and in-depth open-ended interviews conducted with traders, both in and out of leadership positions. The results could not empirically confirm the prevailing discourse on the monopolizing power of female-led market associations. The study

rather finds that traders' collective action provides vital safety-net measures for asset-poor women engaging in risky market activity. However, the public perception is challenging female trader agencies.

The third paper analyzes the role of institutions and focuses on the innovation networks in the sugarcane sector in Brazil. The study combines the novel concept of 'biomass value-webs' with the established National Innovation System concept. For data collection, in-depth interviews and Net-Maps as a participatory tool were applied. The results illustrate the importance of innovation networks for Brazil to become a front-runner in the future bioeconomy. In particular, it emphasizes the importance of integrating national and international private sector organizations, and the need for incentives to foster collaboration with knowledge institutions.

Based on these findings, one can conclude that strengthening the efforts to tailor site-specific solutions that consider the inter-disciplinary nature of crop production, marketing and development of processes is crucial to the bioeconomy. Overall, more attention to innovation networks is required to master the challenges of the bioeconomy and take full advantage of its opportunities.

Zusammenfassung

Eine steigende Anzahl an Ländern hat damit begonnen, eine eigene Bioökonomiestrategie auszuarbeiten. Die Bioökonomie stellt ein neuartiges ökonomisches Konzept dar, das zum Ziel hat, ein nachhaltiges, wissensbasiertes Wirtschaftssystem zu schaffen, das auf der Nutzung biologischer Ressourcen basiert. Auf der einen Seite beinhaltet dieses Konzept eine höhere Produktion von Biomasse. Gleichzeitig ist es auf engere Kollaborationen zwischen nationalen und internationalen Institutionen angewiesen. Institutionelle Netzwerke sind wichtig für die nachhaltige Produktion und Nutzung biologischer Ressourcen sowie die Entwicklung innovativer biologischer Prozesse und Prinzipien. Diese Dissertation betrachtet drei Schlüsselaspekte, um das erhebliche noch ungenutzte Potential der Bioökonomie zu erschließen.

Die erste Fallstudie hat zum Ziel, die Gründe für die andauernd niedrigen Maiserträge trotz der Einführung eines Düngersubventionsprogramms in Nordghana zu erforschen. Diese Politikmaßnahme wird weithin als Instrument betrachtet, Getreideproduktivität zu erhöhen und zur Ernährungssicherheit beizutragen. Die zweite empirische Studie untersucht die Rolle von traditionellen Marktfrauenverbänden in Ghana. Marketing ist ein zentraler Aspekt in der Entwicklung der Bioökonomie, weswegen Handelsorganisationen eine Schlüsselrolle innerhalb der Wertschöpfungskette spielen. Die dritte Fallstudie nimmt Zuckerrohr als Beispiel dafür, wie sich Brasilien als der Weltmarktführer in der Zuckerrohrproduktion positioniert, um den Wandel von einem fossilen zu einem biobasierten Wirtschaftssystem zu vollziehen.

Die zwei Länder Ghana und Brasilien wurden als Fallbeispiele gewählt, weil sie eine vergleichbare Nettoprimärproduktivität und vergleichbare pedo-klimatische Bedingungen aufweisen, sich jedoch auf unterschiedlichen Stufen in der Realisierung der Bioökonomie befinden. Zwei Faktoren sind zentral für eine erfolgreiche Entwicklung der Bioökonomie: Biomasse und Wissen. Basierend auf zwei Fallstudien in Ghana untersucht diese Dissertation zuerst die Bemühungen, die Maisproduktivität in der Guinea-Savanne zu erhöhen, und zum zweiten die Rolle von gemeinschaftlich handelnden Gruppen als zentrale Akteure für die Nachhaltigkeit der Bioökonomie. Brasilien hat wichtige Aspekte einer Bioökonomie bereits erfolgreich implementiert, speziell im Zuckerrohrsektor. Deshalb bietet es sich an, in diesem Kontext die Rolle von Institutionen und Netzwerken in der Entwicklung neuer Prozesse und Produkte zu analysieren.

Diese Studie setzt qualitative wie auch quantitative Methoden ein, um die drei wesentlichen Aspekte in der Entwicklung der Bioökonomie – Produktion, Marketing und das gesamte Innovationssystem – zu adressieren. Die Datenerhebung und -analyse beinhalten Methoden aus verschiedenen Disziplinen. Die Ergebnisse werden in drei Artikeln dargestellt, die gemeinsam diese kumulative Dissertation bilden.

Der erste Artikel arbeitet mit einem interdisziplinären Ansatz. Eine Haushaltsumfrage, Tiefeninterviews und Fokusgruppendiskussionen wurden genutzt, um Daten zu den sozioökonomischen Herausforderungen in der Maisproduktion in der Guinea-Savanne zu erheben. Zusätzlich wurden Boden- und Düngerproben analysiert, um natürliche Einschränkungen und gegebenenfalls bestehende ordnungspolitische Herausforderungen zu identifizieren. Die Ergebnisse dieses Artikels zeigen, dass sowohl sozioökonomische wie auch

biophysikalische Parameter eine Rolle spielen für ein verbessertes Verständnis standortsspezifischer Herausforderungen, die zu geringer Maisproduktivität in der Guinea-Savanne Ghanas, führen.

Der zweite Artikel untersucht – über Regionen, Ethnien und Marktformen hinweg – die Rolle von Marktfrauenverbänden. Für diese Studie wurde ein qualitativer Ansatz gewählt, der teilnehmende Beobachtung und offene Tiefeninterviews mit Händlerinnen beinhaltet. Dieser Artikel konnte den vorherrschenden Diskurs zur Monopolmacht von Marktfrauenverbänden in Ghana nicht empirisch belegen. Die Studie zeigt vielmehr, dass das kollektive Handeln von Marktfrauen zur Schaffung von Sicherheitsnetzen für vermögensschwache Frauen, die an riskanten Marktaktivitäten teilhaben, beiträgt. Der öffentliche negative Diskurs stellt die Marktfrauenverbände jedoch vor Herausforderungen.

Der dritte Artikel analysiert die Rolle von Institutionen und ist fokussiert auf Netzwerke im Zuckerrohrsektor in Brasilien. Diese Studie verbindet das innovative Konzept von „Biomass Value-Webs“ mit dem des „Nationalen Innovationssystems“. Zur Datenerhebung wurden Tiefeninterviews sowie – als partizipative Methode – Net-Maps angewandt. Die Ergebnisse unterstreichen die Bedeutung von Innovationsnetzwerken für Brasilien, wenn es ein Vorreiter der künftigen Bioökonomie werden möchte. Sie betonen besonders die Notwendigkeit, nationale und internationale Organisationen des Privatsektors zu integrieren und Anreize zur Zusammenarbeit mit Wissensinstitutionen zu schaffen.

Basierend auf diesen Ergebnissen kommt diese Dissertation zu der Schlussfolgerung, dass standortspezifische Lösungen unter Beachtung der Multidisziplinarität von Nutzpflanzenproduktion, Marketing und der Entwicklung von Innovationsprozessen entscheidend sind für den Erfolg der Bioökonomie und gestärkt werden sollten. Schließlich sollte auch Innovationsnetzwerken mehr Aufmerksamkeit gewidmet werden, um den Herausforderungen der Bioökonomie zu begegnen und um das Potenzial der Bioökonomie bestmöglich auszuschöpfen.

List of acronyms and abbreviations

BECY	Strategic Network Bio-based Economy
BMBF	German Federal Ministry of Education and Research
EMBRAPA	Brazilian Agricultural Research Corporation
ESP	Exchangeable Sodium Percentage
FGD	Focus Group Discussions
FSP	Fertilizer Subsidy Program
FTIR	Fourier Transform Infrared
GHG	Greenhouse Gas
GPS	Global Positioning System
ICABR	International Consortium on Applied Bioeconomy Research
MoFA	Ministry of Food and Agriculture
MQ	Market Queens
NGO	Non-Governmental Organization
NIE	New Institutional Economics
NIS	National Innovation System
NPK	Nitrogen Phosphorus Potassium
NPP	Net Primary Productivity
OLS	Ordinary Least Square
PLS	Partial Least-Squares
R&D	Research and Development
RMSECV	Root Mean Square Error Of Cross Validation
ROSCAs	Rotating Savings and Credit Associations
SDGs	Sustainable Development Goals
SOC	Soil Organic Carbon
SSA	Sub-Sahara Africa
TFP	Total Factor Productivity
UNICA	Brazilian Sugarcane Industry Association
VCR	Value Cost Ratio

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Chapter 1

Introduction

This thesis explores the policy and institutional environment that is required to foster the emerging bioeconomy in two case study countries, Ghana and Brazil. This work addresses three pivotal issues concerning the development of the bioeconomy. The premise to develop the bioeconomy is high biomass productivity. In Ghana, the conventional cropping system is still suffering from high yield gaps, despite the implementation of the fertilizer subsidy program, widely accepted to be a compelling policy tool to increase yields. Therefore, the second chapter of this thesis investigates in-depth the factors affecting low maize productivity in the Guinea savanna of Ghana. The third chapter analyzes the role of a traditional market institution described, within Ghana, to monopolize the market hindering fair transactions for producers and consumers. The last empirical study investigates the institutional arrangement and the innovation environment along the biomass-value web in the sugarcane sector in Brazil, described as having a great advantage in the upcoming bioeconomy. This work challenges the above-mentioned widely accepted policy beliefs by applying innovative research methods with the aim to identify entry points for the development of strategies based on comprehensive research findings. In this introduction, the background and the problem statement are presented, followed by the objective of the study. An overview of the methods applied, as well as of the study context is given and concludes with the thesis outline.

1.1 Background and problem statement

The increasing world population, demanding for a larger share of resources and producing more waste and Greenhouse gas (GHG) emissions calls for a more sustainable use of the limited natural resources. In this context, renewable resources and among them biomass, have gained importance as an alternative to fossil fuels, in the production and processing of the four “f’s” (food, feed, fuel and “fun” where fun refers to products such as flowers).

The role of biomass has undergone dynamic changes in use, societal and economic importance has grown, and it has become a popular discourse in political strategies and debates. Historically, biomass has been used for the four “f’s”. The changes of allocation and price of biomasses have influenced political decisions and have had repercussions with global effects (e.g. the economic crisis in 2008/09), emphasizing its crucial role. In the mid-21st century, the concept of “bioeconomy” was first developed to address the scarcity of fossil resources, but after new technologies for oil extraction developed and oil prices dropped, the major argument has become climate and environmental protection (German Bioeconomy Council, 2016). However, the increased use of biomass as an industrial resource should not come at the expenses of food security or the environmental or social dimension (Schneider, 2014; Virchow et al., 2016, 2014). Up to now, there exists no unified definition of “bioeconomy,” yet there is a common understanding of the concept that is reported in the Communiqué of the Global Bioeconomy Summit in 2015. The definition given in the report is “bioeconomy as the knowledge-based production and utilization of biological resources,

innovative biological processes and principles to sustainably provide goods and services across all economic sectors" (Global Bioeconomy Summit 2015 p.4). Based on this definition, the term is used in this study.

1.2 The role of networks and institutions

The shift towards the bioeconomy is complex process that entails many challenges but, at the same times opens new opportunities. This is the case across all economic sectors extraction of raw materials, manufacturing and processing, and services. The sustainable bioeconomy "involves systematic approaches (e.g. nexus thinking), particularly innovation policy measures that aim at optimizing Bioeconomy value networks and minimizing waste and losses" (Global Bioeconomy Summit 2015 p.5). This concept is in line with the "biomass-based value web" concept that recognizes the importance of the linkage between value chains through cascading use and the integration of non-food biomasses when analyzing the use of biomass (Virchow et al., 2016). Countries have different factor conditions and through their historical path have reached different stages of biomass production and exploitation. Ways and timeframe in which different countries would succeed shifting towards the bioeconomy depend on their natural condition as well as on the current stages of biomass production and exploitation. Brazil for example, has reached a comparative advantage in the production of sugarcane due to the favorable factor conditions, and the early development of supporting institution, in particular cooperatives and research centers that have fostered the development of the sector (de Moraes and Zilberman, 2014; Furtado et al., 2011; Hira and de Oliveira, 2009; Ueki, 2007). The political commitment and the early investment in the research of an alternative for crude oil have led to fundamental technical and economic efficiency. Brazil has shown that it is possible to substitute fossil with biobased fuels, in particular with sugarcane based ethanol, however, many more substitutions are needed to build a sustainable bioeconomy. Other geographies, with similar natural factor conditions have the potential to reach comparable productivity levels and reach a comparative advantage in biomass production. To identify the opportunities of, in this case Ghana, a country with similar natural conditions but very different political and agro-biomass sector development, it is necessary to identify traditionally rooted institutions and assesses the natural factors, the policies, and governance challenges that influence biomass production. As the Brazil case reveals, the shift to a bio-based economy calls for value networks, transdisciplinary systems and institutional collaborations. This work specifically looks at institutional networks, the role of single institutions and the ambition to apply a transdisciplinary approach. Nevertheless, the development of an economic, environmental and socially sustainable bioeconomy calls for a fundamental change to the current economic system. The literature refers to a "great societal transformation" and sees "profound changes to infrastructures, production processes, regulation systems and lifestyles, and extends to a new kind of interaction between politics, society, science and the economy" (WBGU 2011 p.1). A positive advancement toward this change is the increasing number of countries around the world of 'bioeconomy strategies', adapted to local conditions and regional specializations (German Bioeconomy Council, 2015).

1.2.1 The bioeconomy and the Sustainable Development Goals

The bioeconomy is addressing societal challenges and is in line with the Sustainable Development Goals (SDGs). The International Committee on the Bioeconomy illustrates how the principles of the bioeconomy are linked to the individual SDGs. For the scope of this thesis, only five are highlighted. The following section is based on a commentary in the scientific journal "Nature" (El-Chichakli et al., 2016). SDG2: Zero Hunger: Food security requires increasingly more efficient food production with reduced GHG emissions and water requirements. New processes in farming and the development of molecular diagnostic to reduce input use and provide nutrient rich foods are needed. SDG7: Affordable and Clean Energy: The energy system in many countries is based on scarce and environmentally important resources, or alternatively is unreliable and/or expensive. Alternative processes, based on modern technologies have the potential to offer solutions that combine the generation of bioenergy with other renewables. SDG8: Decent Work and Economic Growth: Modern processes and alternative technologies to crude oil can trigger innovation that supports inclusive and sustainable growth through full and productive employment and decent work for all. In which the terms 'inclusive' and 'for all' implicitly refer to gender empowerment and SDG5: Gender Equality. SDG15: Life on Land: the sustainable use of terrestrial ecosystems, despite the intensification of agriculture, must be guaranteed, which calls for bioeconomic solutions. Agriculture must be disentangled from fossil fuels and excessive use of chemical inputs, while reversing land degradation through ecosystem friendly and locally adapted solutions.

1.2.2 Rationale of the thesis

There is a well-known fable in the oral African tradition, which reached a wider audience when it was told overseas and written down by Dr. James E. Kwegyir Aggrey (1875-1927), an intellectual native of the Gold Coast (modern Ghana), between 19th and the 20th century. The story is about an eagle, which due to its circumstances, was raised as a chicken. When a researcher sees the eagle in the chickens coop, he wonders what it would take for the eagle to unfold his true nature. This thesis follows a similar narrative, hoping to find out what it takes for the bioeconomy to achieve its full potential.

The overarching ambition of this thesis it to "dive deeper" into key issues that would enable the development of a sustainable bioeconomy tailored to the local natural, social and institutional conditions. Understanding the given policy and the institutional environment is essential in order to foster the development of the emerging agro-biomass sector and ensure food security for all actors involved in the value-web. Embracing the bioeconomy depends on the ability from the agro-biomass sector to produce increasing amounts of biomass, to adopt new technologies and farming practices, and also entails engagement in new institutional arrangements along the biomass value-web.

Box 1: "The Parable of the Eagle" by J.E.K Aggrey

A fable is told about an eagle that was raised as a chicken.
When the eagle was very small, he fell from the safety of his nest. A farmer found the eagle, brought him to the farm, and raised him in a chicken coop among his chickens. The eagle grew up doing what chickens do, living like a chicken, and believing he was a chicken. A scientist came to the farm and saw the eagle among the chicken, acting like one. He knew that an eagle is the king of the sky. He was surprised to see the eagle strutting around the chicken coop, pecking at the ground, and acting very much like a chicken. The farmer explained to the scientist that this bird was no longer an eagle. He was now a chicken because he had been trained to be a chicken and he believed that he was a chicken.

The naturalist knew there was more to this great bird than his actions showed. He was born an eagle and had the heart of an eagle; he just needed to unfold his potential. The man lifted the eagle onto the fence surrounding the chicken coop and said, "Eagle, thou art an eagle. Stretch forth thy wings and fly." The eagle moved slightly, only to look at the man; then he glanced down at his home among the chickens in the chicken coop where he was comfortable. He jumped off the fence and continued doing what chickens do. The farmer was satisfied. "I told you it was a chicken," he said. The naturalist returned the next day and tried again to convince the farmer and the eagle that the eagle was born for something greater. He took the eagle to the top of the farmhouse and spoke to him: "Eagle, thou art an eagle. Thou dost belong to the sky and not to the earth. Stretch forth thy wings and fly." The large bird looked at the man, then again down into the chicken coop. He jumped from the man's arm onto the roof of the farmhouse. Knowing what eagles are really about, the scientist asked the farmer to let him try one more time. He would return the next day and prove that this bird was an eagle. The farmer, convinced otherwise, said, "It is a chicken." The scientist returned the following day to the farm, took the eagle and asked the farmer to show him the way to the high mountain that he could see in the distance. The farmer and others from the community who knew the terrain took the scientist to the high mountain. After one day and one night of walking, they arrived at the top from where they could not see the farm nor the chicken coop anymore. Early the next morning the man held the eagle on his arm and pointed into the sky where the rising sun was beckoning. He spoke: "Eagle, thou art an eagle! Thou dost belong to the sky and not to the earth. Stretch forth thy wings and fly." This time the eagle stared skyward into the bright sun, straightened his large body, and stretched his massive wings. His wings moved, slowly at first, then surely and powerfully. With the mighty screech of an eagle, he flew.

This story was selected because it reflects several features of the thesis. As the eagle, the potential of the bioeconomy is not immediately recognized and the scientist can help, but only with the support of the local people can the path can be found to unfold its full potential.

This is an orally transmitted story, however Dr. Aggrey told it on many occasions. Different versions of the story are exist, the above presented version is largely based on Glenn (1994).

Pursuing the ambition of "looking beneath the surface", this thesis has chosen case studies from two countries, Ghana and Brazil. Their different stages in the path towards a bioeconomy, despite the similar natural conditions of the two countries, make them particularly interesting from a research point of view. For the development of the bioeconomy production, marketing, and the overall innovation system are essential elements. Chapter 2 and 3, analyze challenges in crop production and a peculiar marketing aspect respectively, based on case studies in Ghana. Chapter 4 investigates the overall innovation system based on the case study of the sugarcane sector in Brazil, as it lends itself well due to its development. The rational to choose Ghana and Brazil as case study countries is given in detail in section 1.5.2.

Although strategies to achieve food security in rural Ghana have focused on increasing food production, for example though substantial investments in the fertilizer subsidy program, yield gaps among the main agricultural crops are still prominent (Adjei-Nsiah, 2012; GYGA, 2017). Productivity increase remains an underling requirement for use-diversification and for the development of novel products to tap into biomass-based markets for both food and non-food purposes. Therefore, the first objective is to identify the factors that contribute and/or hinder productivity increase of maize in the Guinea savanna of northern of Ghana, by applying a multidisciplinary approach and by combining quantitative and qualitative research methods.

The development of markets plays a key role for all actors in the biomass value web. There is the assumption that considerable hurdles, to a healthy trading system in Ghana, are monopolized markets thorough influential female leaders. Better understanding the power structures and the role of these informal institutions is the objective of the third chapter of the thesis. Traditional institutional arrangements have the potential to be important catalysts in the development of the biomass webs and to achieve food security. However, to pursue this objective they need to be integrated the innovation system.

Brazil has showcased that the successful exploitation of biomass value-webs leads to the independence, to a large extent, from crude oil, and the commitment to develop and invest in sugarcane biomass led to the comparative advantage in sugar and ethanol production. A prominent step of the country towards bioeconomy is the substitution of crude oil based gasoline with sugarcane-based ethanol. By first analyzing the historic path, the aim was to identify which technical and institutional innovations were needed, both to increase productivity and currently for the development of novel processes and products.

However, the aim of the study is to go a "step further" by looking into detail at the three crucial issues related to the development of the bioeconomy. The work applies innovative research approaches by combining novel methods (e.g. biomass value-webs) with well-established ones (e.g. national innovation systems), and qualitative research methods (e.g. focus group discussions) with natural science based approaches (e.g. laboratory based soil and fertilizer testing). Delving deeper into the single issues enables us to reconcile traditional structures and local institutions with the emerging bioeconomy; this is particularly interesting

in the two case study countries. Both have, to some extent, comparable natural conditions but are at different development stages of the agro-biomass sector.

1.3 Objectives of the thesis

In line with the above considerations, the thesis addressed, in separate chapters, three main objectives:

First: Fertilizer subsidy programs are widely accepted policy approaches to increase productivity and contribute to food security; however the predicted effects have not yet been realized. Therefore, the first objective is to determine, through the integration of socioeconomic and natural science based data, the factors that are keeping smallholder farmers from overcoming the persisting maize yield gap in the Guinea savanna of Ghana.

Second: 'Market queens' are described as monopolizing agents compromising fair prices for producers and consumer. Looking beneath the surface of the functions of market associations is important to reconcile institutional arrangements to foster the participation of all actors of the value-webs. Therefore, the second objective of this work is to explore the role and identify the nuances of female-led market institutions in Ghana by applying rigorous qualitative methods. This chapter strives to unravel the public perception on these actors.

Third: The institutional arrangement has led to the comparative advantage of Brazil's sugar and ethanol production. However, Brazil needs to adapt its national innovation system to face the new challenges if it seeks to gain a comparative advantage in the bioeconomy. This study identifies the existing networks that foster the development of innovations, as novel processes and products. But also aims to individuate missing linkages needed to develop the bioeconomy. This study does not aim to quantitatively assess the current innovation performance of the sugarcane value web in Brazil; rather it aims to provide a conceptual basis for such assessments.

1.3.1 Research questions

For each of the above stated objectives of the thesis, the specific research questions are presented below.

The research questions for the objective of analyzing the factors that hinder potentials of the fertilizer subsidy program in the Guinea savanna of Ghana are as follows:

a. Which inputs and soil parameters contribute to determine maize yield in the study area?
b. Which factors effect farmer's decision on fertilizer use intensity?
c. Can the chronically low maize yields be attributed to low quality fertilizer?
d. What challenges do farmers face in accessing the fertilizer subsidy program?
e. What role do site-specific natural factors, such as soil properties and weeds, play in yield variability?
f. What measures are crucial to support maize production for smallholders' farms?

The objective of unraveling the perception and role of female-led market organizations is realized by addressing the following questions:

a. What is the role of the leader in the female-led market institutions and how do they differ between ethics, locations, and market arrangements?
b. How the female-led market institutions structured and what are their functions within the Ghanaian context?
c. What is the source of the discourse, outside the market, on the role of the organization?

For achieving the objective of exploring how well Brazil is positioned to meet opportunities and challenges of the bioeconomy, by exploiting the value web producing novel high-value bio-based products, the research questions are as follows:

a. How does the biomass "move" in the sugarcane value web?
b. Which institutions are linked to the different stages of processing and utilization of the sugarcane biomass in the value web?
c. How are the identified institutions linked through knowledge and business interactions?
d. How well is Brazil prepared to develop competitive bioeconomic products and what can foster the innovation network?

1.4 Governance challenges of the developing bioeconomy

To satisfy the intent of this work to "delve deeper" to identify the governance challenges that prevent the eagle from spreading its wings and flying, the following section reviews the role of institutions as it represents an essential analytical framework for the three empirical chapters of the study. Governance challenges in the considered three aspects, production, marketing and the overall innovation system are crucial to the development of the bioeconomy.

1.4.1 The role of institutions in the latest revolutions

If one takes the definition by the renowned Merriam-Webster dictionary, a revolution is defined as an "activity or movement designed to effect fundamental changes in the socioeconomic situation" (Merriam-Webster, 2017). The mentioned "fundamental changes" happened first in the field of agriculture (Neolithic revolution 10.000 years ago, plants and animals were domesticated) and the population became sedentary and improved manual dexterity and had more time for handcrafts. A second agricultural revolution (1700) has paved the way for the industrial revolution (1760 -1840). In Britain, the increase of land and labour productivity due to the improved farming practices (e.g. drainage systems and selective livestock breeding) and technological innovations (e.g. cast iron plough and seed planting instead of seeds broadcasting) led to more work forces available for activities such as manufacturing which fostered competition, innovations and efficiency. However, also the change in land tenure systems, the development of national markets, and the improvement of the transportation infrastructure fostered innovations and agricultural productivity. The

following population increases in England and Wales, and the decline of labor force needed in agricultural of that laid the foundations for the Industrial revolution (Overton, 1996).

The most recent revolution in agriculture is the so-called 'green revolution' (1960), which saw a massive increase of rice and wheat yields due to the introduction of new varieties and complementary chemical inputs in Asia. The bioeconomy is an element of the "great societal transformation" (WBGU, 2011). This definition introduces, aside from the technological innovations, the social aspect, which is pivotal to make a successful shift from the current fossil-based to the envisioned bio-based economic system. Banerjee (2013) shed light on the role of institutional and political actors that accompanied the success of the green revolution. She finds that to sustain a long-term agricultural growth is only possible through the establishment of a functioning infrastructures and institutions. Furthermore, analyzing the case of the green revolution in India she emphasize the role of leadership and political-will both at the local and the policy level. The debate on technological and demographic factors against the role of political and institutions is also known as the "Brenner Debate", due to the seminal work of Robert Brenner in 1976. In his work he compares the adoption of agricultural technologies to the more independent family farms in Western Europe, and the more restrictive system, which did not incentivize the uptake of productivity increasing measures, in the feudal structures in Eastern Europe. The study highlights the role of institutions in taking up productivity-increasing technologies in pre-industrial Europe with effects that are lasting till today. The development of an economic, environmental and socially sustainable bioeconomy calls for a fundamental change to the current economic system. With regards to this, the literature oftentimes refers to a "great societal transformation" (WBGU 2011 p.1). The bioeconomy could represent a necessary next revolution but, the critical components have to be considered: Political-will, engagement of institutions at local, regional and global level, development of innovations and that foster an efficient and sustainable use on natural resources. A positive advancement towards this change is the increasing number of countries around the world have adopted a 'bioeconomy strategies', tailored to local conditions and regional specializations (German Bioeconomy Council 2015).

1.4.2 Definition of Institutions

Douglas North, leading author of New Institutional Economics (NIE) defines institutions as "the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)" and their enforcement characteristics (North 1991, p.97). However, interactions between actors can also be catalyzed by formal and informal institutions. For the purpose of this thesis, it is useful to distinguish between institutions and organizations. Institutions are defined as "the rules of the game" (North 1993 p.3), whereas an organization can be defined as a group of people working towards a common objective and sharing common regulations. Cooperatives and the female-led market organizations are, however, both at the same time. The NIE authors argue that both organizations and institutions have developed through reducing transaction costs and obtaining higher efficiency in economic performance (Bardhan, 1989; Coase, 1984; Williamson, 1979). Transaction costs arise when agreeing on a contract and when enforcing

it. Social benefits are undermined by the failure of a gainful transaction to be realized because of transaction cost, such as screening and monitoring contract partners for example. The failure to exhaust the possible lucrative transaction is a market failure[1] (Coase, 1937; North, 1990).

1.4.3 Governance challenges

Information asymmetries are a prominent type of transaction cost leading to opportunistic behavior and *'market failures'* (Akerlof 1970) . Development of new processes and products is capital and knowledge intensive but pivotal for the development of the bioeconomy. Private sector investment might be discouraged due to high initial costs and economies of scale can leading to monopolies (De Janvry et al. 1997). Policies that foster the engagement private firms and stimulate competition (e.g. start-ups), strengthen institutions (e.g. collective action organizations) and property rights, can help to overcome market failures (Jayne & Tschirley 2009). Moreover, the public good characteristic of some of the innovations further discourages the commitment of the private sector, calling for government investments. Asymmetric information and transaction costs are prominent causes leading to market failure in credit provision; this is especially true in the case of collateral poor actors in the value chain, usually performing small transactions which can also involve *'coordination failure'* (Kydd and Dorward, 2004). Local peer-to-peer saving and credit associations can be a solution, as in the case of female-led market institutions in Ghana. Coordination failure can have a particularly damaging effect in an interlinked and multidisciplinary network, as it is envisaged by the bioeconomy strategy. As for example actors are directly affected by not making an investment due to a possible absence of complementary investments at a different stage in the value-web (Kydd and Dorward, 2004).

Therefore in a complex system, *'network failures'* are especially relevant the knowledge-based bioeconomy, as showcased in the sugarcane sector in Brazil's bioeconomy. Government is considered able to alleviate knowledge specific failures. Problems of interaction between stockholders or actors, due to poor linkages, limited trust and high (perceived) transaction cost are defined network failures (Arnold and Thuriaux 2003). The same authors define capability failures as for example poor managerial capability of technological knowledge and the inability to make use of externally generated technology for their own best interest.

Infrastructure and market stability are preconditions for the successful development of the agro-biomass sector, innovations and the overall bioeconomy. The lack of provision of public goods, merit goods, and services, which create positive externalities (benefits that can have a significant effect on social welfare), is a detrimental *'market failure'*. The case of the subsidy program in Ghana reflects the lack of investment in extension service, in capacity building of local institutions and infrastructure to provide timely subsidies, which affects the overall

[1] When resource allocation is suboptimal in the sense of Pareto, one can refer to a market failure. This implies that the welfare of one individual could be improved, without affecting the welfare of others (Bator, 1958). "Failures" of the public, the private and the third sector are referred also to as "governance challenges" (Birner and Anderson, 2007)

success of the program. Moreover, due to information asymmetries, those who are not accessing the education would under value its benefits (Musgrave, 1959). The German bioeconomy council also refers to the knowledge-based bioeconomy, highlighting the investments in knowledge resources as one of the most powerful instruments of governments to develop the bioeconomy (German Bioeconomy Council, 2013a).

Public sector organizations can promote the development of the bioeconomy through policy instruments, especially by strengthening the demand side of bioeconomic products, as Brazil has done by developing flex-fuel cars. Support programs for industrial and research initiatives that foster the transdisciplinary collaboration are pivotal. This also implies a high commitment from all stakeholders to coordinate efforts, e.g. private sector, government institution, research agencies (de Moraes and Zilberman, 2014; Furtado et al., 2011; Hira and de Oliveira, 2009). This was observed in the case of the development of the bioeconomy strategy in Brazil. Government interventions can themselves be confronted with another typology of failure related to governance challenges at the public institutions level, namely *'state failures'*. Elite capture intended as the capacity of "elites" to maneuver benefits from government programs towards themselves; Clientelism described as the allocation of resources to a specific group and political targeting refers to the allocation to a targeted location both in expectation of political support; Corruption as bribes in exchange for goods and services to name some. The case of the fertilizer subsidy program described in chapter two reflects the above mentioned governance challenges.

Organized groups of individuals, like communities or other forms of formal and informal institutions, can play an important role in addressing market and state failures. Third sector organizations (non-governmental and community-based organizations), face their own challenges referred to as *'community failure'*. Common challenges of e.g. Farmer-based organizations are classic free-rider problems of collective action (Ostrom, 1990). Moreover marginalized groups often face challenges in entering such organizations, due to gender norms or wealth, and social reasons (Agrawal and Gibson, 1999; Birner and Anderson, 2007). Management, technical capacity and financial constraints are some of the challenges of participatory approaches as well as the above mentioned prominent elite capture problem (Platteau and Gaspart, 2003). Coordination and monitoring by group members contributes to good governance of the community or group, as seen in the example of the female-led market organizations in Ghana.

1.5 Methodology

This section fist describes the broader study context of the thesis; the BiomassWeb project and the choice for the two case study countries, Ghana and Brazil. Following, the innovative methodological approaches used in the three empirical studies are outlined, which allowed for a 'look underneath the surface'. An overview of the methods is presented here, however, specific details for each study are fully explained in the respective chapter.

1.5.1 Study context: the BiomassWeb project

This thesis is embedded in a larger project "BiomassWeb" which is funded by the German Federal Ministry of Education and Research (BMBF) supported with funds from the German Federal Ministry for Economic Cooperation and Development as part of the GlobE – Research for the global food supply program. The projects underlying assumptions are: (i) that Sub-Saharan Africa (SSA) has high natural potential to increase biomass production (ii) the actual available biomass is underutilized.

BiomassWeb aims therefore at contributing to food security in SSA by focusing on biomass-based value webs. The project seeks to use a multidimensional approach (biomass value-webs) to identify and quantify potential opportunities to extract or create value. Biomass-based value webs are complex systems of interlinked value chains in which food and fodder, fuels, and other raw materials are produced, processed and traded. The overarching goal of BiomassWeb is to provide concepts on how sub-Saharan Africa may increase availability and access to food through more and high value biomass for both food and non-food purposes in the next two decades or more; in light of an increasing (local to international) demand for more and innovative biomass products from agriculture in the next decades. This goal is perused by identifying biomass-based value webs and studying selected entry points to increase the overall system productivity through exemplary agronomic, technological and institutional innovations. This thesis is part of the work-package "Governance" and focused on the institutional component, which deals with policy an institutional environment that is required to foster the emerging agro-biomass sector and at the same time to ensure food security for smallholder farmers by integrating them into the emerging international bioeconomy (FSC and ZEF 2013 p. 8 and 93). Among the three project countries Ghana, Ethiopia and Nigeria, Ghana was chosen for the case studies of this thesis.

1.5.2 Study context: Ghana and Brazil

The two chosen countries have different institutional setups and are at different development stages of the bioeconomy. Ghana represents an interesting case as knowledge institutions, in particular agricultural research, extension and education systems, as well as the regulatory and policy environment have not yet developed a strategy for the development of the emerging agro-biomass sector. However, locally important institutions, (e.g. trader associations), and policies aiming to increase biomass productivity (e.g. fertilizer subsidy programs), are in place and can play a significant role in the development of the bioeconomy.

The first step for the development of the bioeconomy is the increase of biomass productivity of traditional cropping systems; persisting yield gaps and low crop productivity are a major

concern in most of Sub-Saharan Africa (Adjei-Nsiah, 2012; Dietrich et al., 2012; GYGA, 2017; Johnston et al., 2011). A popular policy approach adopted by governments in the region is the implementation of input subsidy programs. However, in the Ghanaian context this measure did not ensure higher yields yet, instead contributed to high public expenditures. Therefore, the second chapter of this thesis seeks to explore the current challenges in the maize production system. The underlying assumption of the BiomassWeb project is also that income generation can be achieved not only through the increase in food cops yields, but also through diversification of the range of products in order to tap into emerging biomass-based markets (FSC and ZEF, 2013). The adoption of technical and institutional innovation in the bioeconomy requires well-functioning institutions coupled with supportive regulatory and policy environments. In this regard, female led-organization in the Ghanaian food crop value chains play a pivotal role, as they are well integrated agents in the biomass-value web and can leverage knowledge about alternative biomass uses in along the value chain and value web. Thus, only by understanding the role of traditional institutions and the power structures in a collectivist society, as Ghana, a successful strategy can be pursued. Therefore, the third chapter aims to shed light on female led-organization in the Ghanaian food crop value chains. Brazil was chosen because of its path and successful achievement of an important step towards a more sustainable economy. Analyzing what it took Brazil to largely incorporate sugarcane biomass in its energy matrix, which is about 17% percent of the total energy consumed in the county (Leão de Sousa and de Carvalho Macedo, 2011), can lead to an understanding and development of strategies for countries that have similar goals. Brazil substitutes transport fuels with sugarcane biomass and recently started sourcing from it for electricity production. Other parts of the world could, considering net primary productivity (NPP)[2], have the prerequisites, theoretically, to achieve similar success rates. In the region of São Paulo where most of Brazils the sugarcane is produced the NPP is comparable to large areas on the African continent (Figure 1). Furthermore, constrains to agricultural production are to some extend comparable in terms of climate, soil and terrain slope are also largely comparable (figure 2). Similar factor conditions in the two regions can facilitate the identification of interventions that have been conducive and can be transferred. This can foster the timely and efficient introduction of material and processes based on biomass. Leapfrogging of technologies can support the prerequisite of the bioeconomy of efficient resource utilization and sustainable agricultural production (German Bioeconomy Council, 2013b).

[2] NNP quantifies the amount of atmospheric carbon fixed by plants and accumulated as biomass.

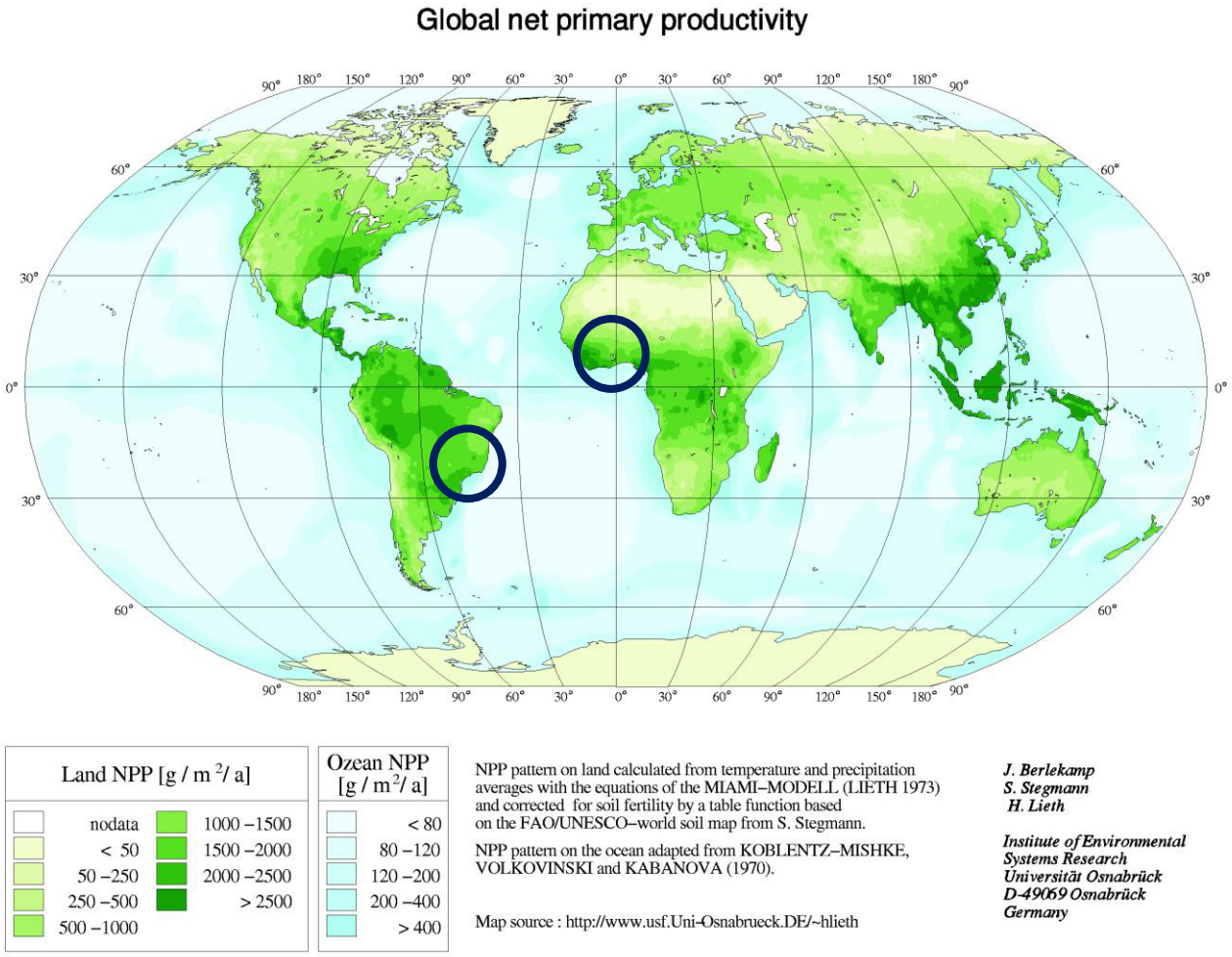

Figure 1: Global net primary productivity
Source: http://www.usf.Uni-Osnabrueck.DE/-hlieth

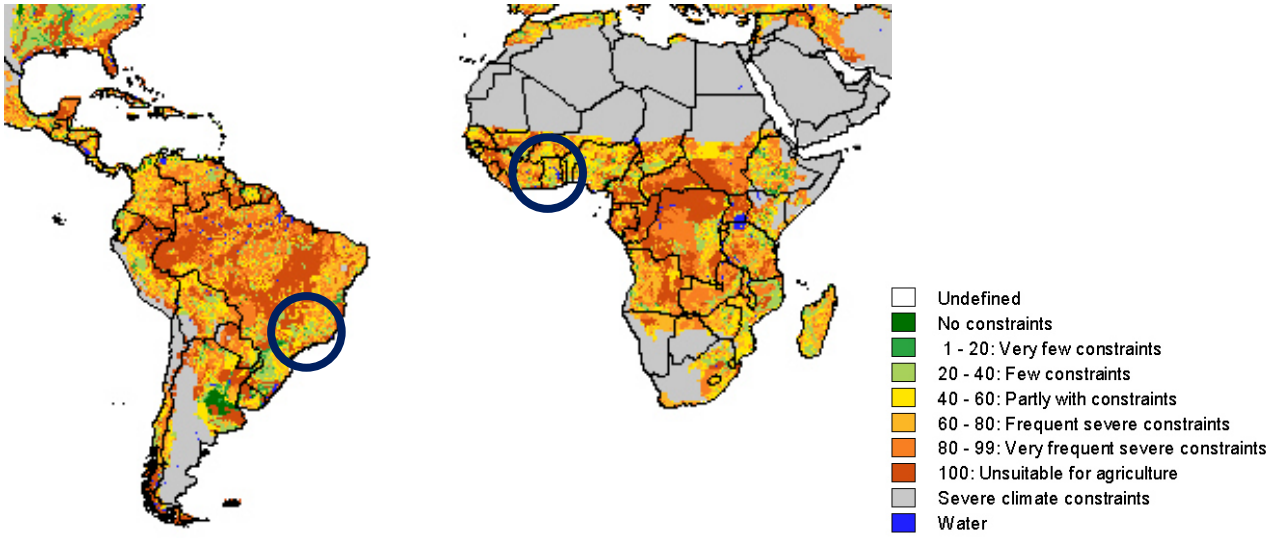

Figure 2: Climate, soil and terrain slope constrains to agriculture production combined (FAO)
Source: http://webarchive.iiasa.ac.at/Research/LUC/GAEZ/index.htm

1.5.3 Description of the qualitative and quantitative methods applied

The second chapter of this thesis takes advantage of a mixed method approach to identify the bottlenecks for increasing productivity in the Guinea savanna of Ghana. The complexity of this pursuit calls for the adoption of an approach that can cover both the natural components (e.g. soil properties), and socio-economic factors. The use of comprehensive methods is pivotal in understanding the influence of natural conditions, management and the fertilizer itself on maize yield. The combination of quantitative and qualitative research tools enables the identification of governance challenges in the fertilizer subsidy program. This study used a conventional household survey in five districts in the northern region. Within each district three communities were randomly selected from the entire list of communities. At the community level, 20 households were randomly selected from a list of farm households. This approach yielded a datasets of 300 households. Previous studies had identified soil characteristics as a limiting factor to grain yields in sub-Saharan Africa (Braimoh and Vlek, 2006; Burke et al., 2017; Marenya and Barrett, 2009). Therefore, for each household one plot cropped with maize in 2015 was randomly selected and detailed data was recorded. The soil samples collected at plot level were analyzed in the laboratory by means of Fourier Transform Infrared (FTIR) spectroscopy, a method which allows the efficient prediction of soil properties at low cost and time efforts but with high accuracy (Bellwood-Howard et al., 2015). The analyzed soil properties reflect common potentially growth limiting soil factors. Similarly, fake and/or adulterated fertilizer is a concern in many countries and has a detrimental effect on trust in the application, as well as in economic terms (Bold et al., 2017; Khor and Zeller, 2014; Sanabria et al., 2013). Therefore, at randomly chosen shops in the study region, NPK fertilizers from the six major brands in the country were purchased using a covered shopper approach. The 100 fertilizer samples were tested for their chemical composition at the 'Core Facility' at the University of Hohenheim to compare the indicated composition on the fertilizer labels with the actual content. The socio-economic data and the soil sample results were used to compute a translog and a Tobit model. The production function has been widely used in farm efficiency analyses for both developing and developed countries (e.g. Evenson, 1989; Khor and Feike, 2017; Riera and Swinnen, 2016). In a further step, factors affecting application rates were evaluated through the use of a Tobit model. The Tobit model is chosen because of the high prevalence of farmers who used zero fertilizer (20%), since it accounts for the qualitative difference between zero and nonzero observations (Wooldridge, 2010).

The translog function was adopted to identify, in a first stage, the inputs that influence maize yield in the context of northern Ghana. This study includes soil specific data, which (not combined in a soil index) to identify which soil characteristic influenced output the most. Through the ordinary least square (OLS) regression, the study identified the management measures that have an impact on yield output. Additionally, focus group discussions (FGD) in each community were conducted to assess the challenges faced at community levels regarding input supply, production and marketing. Focus group discussions conducted at community levels were chosen because of their ability to generate efficient and interactive contextual information (Morgan 1998). The FGDs were scheduled in times and locations convenient for

the participants and were moderated in local languages and considering local norms to encourage open sharing of knowledge.

The third chapter is a purely qualitative study. To ensure the quality of the empirical data collected on one hand and on the other to be able to "look under the surface," a combination of research methods was applied. In the first step, a comprehensive literature review was carried out, which revealed a lack or low availability of empirical data on the market structures and exposed a violent discussion in social media and "gray" literature about the function of female leaders in the power structure of the market. Secondly, sourcing from the grounding theory approach, interviews were conducted with market traders, both in leadership positions and not, covering all regions and a large number of dominant ethnic arrangements and market types, until reaching theoretical saturation (see Corbin and Strauss 2008). Interviews in general differ from conventional exchange of perception because they follow a structure and a purpose (Gilbert, 2008). Rich qualitative information was collected from in-depth open ended interviews. This type of data collection method is particularly suited for this case since it enables us to capture the complexity of a topic, the nuances and insides of socially and politically sensitive topics (Creswell, 2009; Johnson, 2002). To gain a richer understanding of the complexity of the daily market life and to accurately captured the functioning of existing networks and gain insight into the views on the matters, these topics were discussed with participants directly and participant observation was employed. The selection of interviewees was done through purposeful sampling, determined by: (i) Commodity sold. The traders interviewed were selling cassava, plantain and maize in the South and dried fish, yam and maize in the North. Maize is common nationwide, cassava and yam represented the prevalent starchy stable crops in the South and in the North respectively, and plantain and fish were chosen because of their importance in the regional diet. (ii) The role they have in the market network. The data was collected from market traders and market traders with leadership roles (when available); Additional informants (traders) in the market were selected by snowball sampling (see Biernacki and Waldorf, 1981:141). Peculiar feature of this study is also the nationwide coverage of the interviews.

The third empirical study presented in Chapter 4 of this thesis combines two conceptual tools to identify the potential of the sugarcane sector in Brazil to develop a comparative advantage in the bioeconomy. The first one is the biomass-based value web, which was developed as an extension of the value chain concept with the aim to capture the links within and between value chains that arise from the cascading use of biomass (Virchow et al., 2016). Once determined, the interrelation and linkages between biomass flows as well as the institutions involved were identified. At this point, interviews were conducted at the respective institutions making use of the Net-Map tool developed by Eva Schiffer (2007) to capture a comprehensive picture and empirically assess the linkages among the actors. During the Net-Map exercise respondents were asked to identify the actors involved in the traditional sugarcane products as well as potential sugarcane biomass uses for novel products and processes. By identifying the institutions involved, the maps gave an overview of the innovation network from a bioeconomy perspective. The interviews also served to identify organizations that did not appear in the mapping of the biomass value webs, but which were

seen as relevant for innovation in the value web. Subsequently, respondents were asked to categorize the collaboration as knowledge flows (formal and informal including personnel) and business linkages. Once created, the maps applied the National Innovation System (NIS) concept. This was as originally developed in the 1980s by researchers who aimed to understand the structure of and the actors involved in processes of innovation in some industrialized and emerging economies (Balzat and Hanusch, 2004). An essential contribution of the NIS literature is the insight that innovation does not only rely on investments in research and technology development solely, but that synergies within and between science, technology, economy, policy and culture along with complementarities between regions and the whole country play an important role (Freeman, 2002). As shown in the NIS literature, the types of relationships between actors play a crucial role for the performance of a NIS. Non-market oriented and stable (long-term) relations improve information transfer as well as interactive learning, because actors can build on "power, trust and loyalty" (Lundvall et al, 2002, p. 218). The definition of the NIS emphasizes the importance of the learning capability of a nation, the organization of financial support and a business service that generates and trades knowledge (Lundvall et al., 2002). Therefor it applies well to the analysis of the sugarcane sector in Brazil. Social Network Analysis (SNA) is used for a quantitative assessment of the knowledge and business linkages that were identified in the value web. Following Pyka (2002), three measures of social network analysis were applied: centrality measures for degree, closeness and betweenness. These measures were applied to identify how well Brazil is prepared to develop a competitive bioeconomy innovation network. The measures capture important preconditions for Brazil's ability to make use of new opportunities and develop a competitive value web based on sugarcane biomass. The links were analyzed using the social network analysis method. The UCINET software was applied to illustrate the final networks and calculate statistical network indicators, specifically degree, closeness and betweenness centrality among actors. Moreover, to measure the cross-links within the network the adjacency matrix was employed (Hanneman and Riddle, 2005). For this purpose, the actors in groups were clustered in namely: Industry, national and international breeding institutions, international biotechnology firms, research institutions and universities. The simplification enabled the calculation of the percentage links that were observed out of all possible links within the clusters. This study does not aim to quantitatively assess the current innovation performance of the sugarcane value web in Brazil; it rather aims to provide a conceptual basis for such assessments.

1.6 Structure of the thesis

As has been described above, the overall motivation of the study is to understand the role of networks and institutions to enable the eagle to fly and the bioeconomy to develop. The following outline provides a synopsis of the following chapters that form the main body of the thesis.

Chapter 2: Fertilizer subsidy programs are expected to promote food crops productivity. This chapter delves deeper into the complex set of factors that prevent the closure of maize yields gaps in the north of Ghana by considering a multitude of natural, socio-economic and institutional variables. To succeed, qualitative and quantitative research methods were applied and natural science parameters were combined with socio economic data.

Chapter 3: Within Ghana female-led market institutions are commonly identified to monopolize the market structure. This chapter is an in-depth study covering the broad spectrum of female-led market associations in Ghana. The study first gives an overview on the available literature that largely pictures market women as cartel organizations. Empirical data was collected in all ten regions and across market typologies. The study challenges the largely spread representation of female-led organizations. In particular, the chapter analyses the role and power of the discourse on women empowerment.

Chapter 4: In Brazil the first steps towards a bioeconomy have been undertaken. By employing a combination of innovative tools, the biomass value web and the national innovation system concept, this chapter seeks to identify the linkages and missing links in the innovation network that are conducive to the development of novel product and processes to assert its position in the bioeconomy.

Chapter 5: Collates the insights from the single studies in the form of a general discussion. From these findings, policy recommendations are derived and discussed. The final chapter also brings up limitations of the study. The chapter closes with the overall conclusions from the study.

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Chapter 2

Soil, striga or subsidies? Determinants of maize productivity in northern Ghana

Lilli Scheiterle[1], Volker Häring[2], Regina Birner[1] and Christine Bosch[3]

Abstract

High yield gaps persist in sub-Saharan Africa and increased fertilizer use is considered among the crucial measures to increase productivity. Despite high government investments, particularly in fertilizer subsidy programs (FSP), overwhelming evidence has revealed their inefficiency. This study employs a multidisciplinary approach to identify the determinants of low maize yields in the Guinea savanna zone of Ghana. We conducted a socio-economic household survey and analyzed plot specific soil samples. Econometric models were estimated based on both socio-economic and soil variables. The results show that a common parasitic weed, striga, and labile soil structure have significant effects on yield in the study region. Plot sizes were recorded both from farmers' direct elicitation and using GPS devices. Considerable discrepancies were detected between self-reported and GPS-measured plot sizes. Fertilizer samples from randomly selected agro-input shops were analyzed to control for adulterated or fake inputs. The measured nutrient contents of the samples reflected the composition indicated on the package labels. Findings underline the need of site-specific data collection, supported by laboratory-based soil test results, to efficiently address low productivity. Although there are no signs of fertilizer adulteration, governance challenges persist in the targeting, timing and elite capture in the distribution system of the subsidy program. The study shows that the FSP has not been an effective standalone measure. Rather, the government needs to invest in capacity building and extension services to address the site-specific problems through comprehensive soil fertility management techniques and weed control. Promoting soil carbon management, minimum mechanical stress, crop rotation, and permanent soil cover should be further investigated as options for the region.

Keywords: Fertilizer subsidy, soil structure, striga, fertilizer quality, land size.

[1] Hans-Ruthenberg-Institute, Social and Institutional Change in Agricultural Development, Wollgrasweg 43, 70599 Stuttgart, Germany

[2] Institute of Geography, Department for Soil Science and Soil Ecology, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum, Germany

[3] Hans-Ruthenberg-Institute, Rural Development Theory and Policy, Wollgrasweg 43, 70599 Stuttgart, Germany

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2.1 Introduction

Population growth in Africa is increasing at a far higher rate than its agricultural productivity. To reduce food insecurity, improve diets, and increase incomes, agricultural yields need to increase (von Braun et al., 2004). Globally, the widest crop yield gaps were observed in sub-Sahara Africa. For example, maize yields were as low as 16% (tropical lowland) and 36% (subtropical regions) relative to the biological yield potential (Lobell et al., 2009). Sub-Saharan Africa has the fastest growing population in the world, leading to increased pressure on natural resources (Le et al., 2016). One of the largely accepted options to address low productivity of food crops is the increased input use, especially of fertilizers (World Bank, 2007). During the African Fertilizer Summit held in 2006 in Abuja, African member states committed to increasing fertilizer use to 50 kg/ha by 2015 to address stagnation in crop production, declining fertility, and rising food insecurity to achieve the "African Green Revolution". Even if there are agronomic concerns about such a blanket approach, at least it reflects a commitment. Since the 'Abuja Declaration', a large number of African states have (re)introduced fertilizer subsidy programs (FSPs) (Druilhe and Barreiro-Hurlé, 2012). Nevertheless, there is overwhelming evidence which shows that such a measure has not resolved low productivity problems. However, there is no agreement in the literature regarding the reasons why the expected effects of fertilizer subsidies programs have not been realized. Socio-economic studies have focused on inefficiencies in the implementation of subsidy programs and highlighted the following reasons: poor targeting of recipients and timing challenges in fertilizer delivery (Banful, 2009; Crawford et al., 2006; Druilhe and Barreiro-Hurlé, 2012; Houssou et al., 2017; Low and Waddington, 1991; Smale et al., 2011). Some studies found fake or adulterated fertilizers as undermining the expected effect of fertilizers (Bold et al., 2017, 2015; Khor and Zeller, 2014; Liverpool-tasie, 2014; Liverpool-Tasie et al., 2010). There is also evidence that the heterogeneity in returns from fertilizer subsidies across different study regions may partly be attributed to statistical artifacts because productivity based on farmer's self-reported field size estimation was found to be distorted (Ajayi and Waibel, 2000; Carletto et al., 2013, 2016). In the natural science literature, agronomic factors have been identified as major causes of low grain productivity. They include problems regarding the nutrient balance, land quality and management (Bindraban et al., 2000; Bronick and Lal, 2005; Häring et al., 2017; Mueller et al., 2012). A small body of literature has analyzed the complementary effects of agronomic and socio-economic factors (Burke et al., 2017; Marenya and Barrett, 2009).

This study aims to take the latter approach a step further by pursuing the two following objectives: To identify how different socio-economic and environmental factors affect maize yield and to analyze governance issues of the Ghanaian FSP. To pursue these goals, we conducted a case study on maize production in Ghana. We simultaneously collected and analyzed a range of data that have, so far, not been included in one single study: (a) socio-economic data; (b) data on targeting of fertilizer subsidies that were derived from a standardized household survey, focus groups and expert interviews; (c) data on striga weed (*Striga hermonthica*) incidence that was collected, for increased accuracy, with the help of pictures representing different percentages of the weed infestation; (d) GPS measurements of

farmers' field size to avoid distortions identified in earlier studies; (e) a lab-based analyses of fertilizer samples to test for fertilizer quality; and (f) lab-based analysis of soil samples to investigate the role of soil fertility in combination with the above data. Using production functions, the socio-economic and environmental data were jointly analyzed to identify the factors that undermine the potential of FSP to increase maize yields. Governance challenges were analyzed using lab data on fertilizer quality and qualitative data of focus group discussions and expert interviews.

Ghana has been selected as a case study location since it has operated an extensive FSP since 2008 (MOFA, 2015). The program was initially designed to cover 50% of the price through a voucher system which was not targeted to a specific crop or a specific category of farmers. The policy was implemented rapidly to counter high fertilizer prices in 2007. In 2010, a waybill receipt system was introduced to address high administrative costs. This universal system enabled all farmers to access fertilizer at the subsidized prices (Banful, 2011; Benin et al., 2013; Houssou et al., 2017). From its inception in 2008 to 2014, a total of 45.9 million USD has been spent on FSP (MOFA, 2015). Since 2013, a card or passbook (free of charge) was issued by the local ministries office that entitles targeted smallholder farmers to receive ten bags of compound fertilizer at a subsidized rate (22.6% reduction) and five bags of urea (20% reduction). This system has now been upgraded by enabling a mobile phone-based SMS-code system, which was partly in place in 2016 (MoFA, 2016). The government's target for the 2015 cropping season was to subsidize 180,000 Mt fertilizer at a cost of 22.3 million USD. This corresponds to approximately 20% of the national budget allocated to the agricultural sector (Oxford Business Group, 2017). In spite of the substantial amount of funds spent on fertilizer subsidies, evidence suggests that little output growth has been recorded, especially in the Ghanaian Guinea savanna zone (Houssou et al., 2017; Ragasa et al., 2014; Ragasa and Chapoto, 2017).

The findings of our study highlight the need to pay attention to both biophysical and socio-economic variables when analyzing yield response to fertilizer subsidies. Important factors that limited maize yields were (a) labile soil structure, which was observed onsite and identified by the interaction of the exchangeable sodium percentage (ESP) and the proportion of silt, and (b) incidence of striga weed. Regarding governance challenges, the study revealed a mixed picture: In contrast to other studies, the lab analysis of the fertilizer samples did not indicate problems regarding fertilizer quality. However, targeting problems of earlier studies were confirmed. Very few farmers owned a card that allowed them to benefit from the government subsidy. Qualitative information indicated that rent-seeking and clientelism have led to the poor targeting.

This chapter is structured as follows: The following section describes the study area and the data collection methods. Section 3 presents the empirical model used for analysis and the results are presented in Section 4. Section 5 presents the discussion and the derived policy implications, Section 6 concludes the chapter.

2.2 Study area and methods

2.2.1 Study area

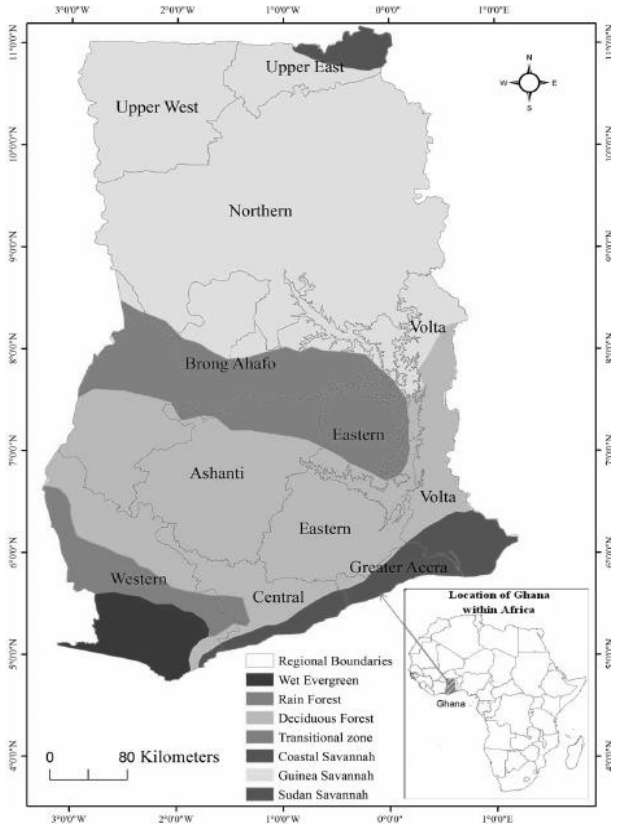

Figure 3: Map of Ghana with regions and agro-ecological zones
Source: Antwi et al., 2014

The study was conducted in the north of Ghana, in the Guinea savanna zone, which includes the Upper West and the Northern regions (Figure 1) and accounts for 57% of the national land area (Olsen et al., 2013). Agriculture contributes to over 60% of employment, even though the region is characterized by low agricultural productivity (GGS, 2015). The Northern region contributes substantially to the overall maize production in the country and ranks fifth in the country's maize production (three years average, 2013-2015), mainly because of area cultivated (MoFA, 2016). The southern regions rank higher as they rely on two rainy seasons and two harvests a year. Nevertheless, of the three agro-ecological zones (coastal, forest and savanna), the savanna zone hosts 40% of all maize growing households and contributes 62% of maize harvest value (Ghana Statistical Service, 2014). However, the high potential of the nearly 400 million hectares of Guinea savanna in Africa remains underutilized, and it is considered "the world's largest agricultural frontier.[3]" Currently, 10% are cultivated, but the savanna has the potential to raise the continent's food production to such an extent that Africa would become a net food exporter (World Bank, 2009). However, there are a number of challenges that need to be investigated and addressed to exploit its potential.

In the Guinea savanna zone, agriculture is predominantly rainfed with a low degree of mechanization. Maize is cultivated permanently on plots close to the homesteads or on plots further away under shifting cultivation. In large parts of northern Ghana, soils are low in soil organic matter and clay content, which contributes to the spatially widespread low cation exchange, low water holding capacities and low nutrient supplies (Bellwood-Howard et al., 2015; European Commission, 2013; Häring et al., 2017).

[3] Jennifer Blanke, Vice-President for Agriculture, Human and Social Development of the African Development Bank, made this statement at the 2018 World Food Prize side event in Des Moines on the 18th of October 2018.

2.2.2 Data and sampling technique

Data collection involved a combination of quantitative and qualitative social science methods as well as lab-based natural science methods. Data were collected from twelve communities in the Guinea savanna.

The household survey was based on a two-stage cluster sampling approach. First, five districts were randomly selected out of 37 in the agro-ecological zone. Subsequently, three communities were randomly selected within each district. Only households growing maize for home consumption and/or sale were targeted. The 300 households[4] participating in the study were randomly selected from a list of all households in the selected communities. Household- and maize plot-level data were collected between May and August 2016, using a structured questionnaire to elicit recall responses on farm production. Data from the questionnaire was collected from a household member responsible for managing a specific plot and included variables such as crop outputs (maize grain, green maize is not harvested in the region), variable inputs (family and hired labor, disaggregated for activity, fertilizer and other inputs), striga incidence, details on the plot manager (gender, age, education) and services received in the last year (credit, extension). From each specific plot, volumetric soil samples were taken at 20cm depth from three different positions within each plot. The three replicates within a plot were combined to one sample (specification in appendix 1). Pictures were used to ensure a common understanding of weed pressure intensity. To ensure data accuracy of plot size data, plot borders were measured with a GPS device by walking around the plot perimeter with the farmer. This approach made it possible to control for deficiencies derived from the respondent error in reporting the plot size, which is acknowledged in literature but, unable to be verified otherwise.

Focus group discussions with an average group size of 21 farmers were held in all the 15 communities selected for the survey. The goal was to cross-check determinants of application rates, identify aspects of fertilizer supply and constraints faced in agricultural production, access to extension services, and marketing of agricultural products. Twelve key informant interviews were conducted with ministry officials, researchers, and individual farmers. The combination of different methods allowed for triangulating the information received and evaluating the perception of FSP's performance, which is particularly important for deriving policy implications. To get samples of NPK fertilizer, 34 local retail shops were randomly sampled in the study region. At these shops NPK fertilizer bags were purchased from brands that are part of the FSP and those that are not, using a covert shopper approach. The covert shopper was impersonating a poor farmer from the region who wants to purchase fertilizer for his small farm. In addition, fertilizer samples were collected directly from those interviewed farmers who still had the original package. Fertilizer samples (n=100) from six common brands in the region were analyzed for nitrogen (N), phosphorus (P) and potassium (K) contents to test whether the fertilizer was accurately labeled

[4] A farm household was defined as members that live in the same dwelling space, eat together commonly prepared food, work on at least one agricultural plot together and acknowledge a common household head.

2.3 Empirical Model

A translog production function, widely used in farm efficiency analyses for both developing and developed countries, was used to identify factors affecting maize output for the sampled households. The use of a single-equation model depicted in Equation 1 assumes that farmers maximize expected profits.

The specific model estimation is:

$$lnY = \beta 0 + \beta 1\ lnL + \beta 2 \ln Lab + \beta 3 \ln Fb + \beta 4 \ln Ftd + \beta 5 \ln Hr + \beta\ 6 \ln St + \\ + \beta\ 7 \ln \text{SoStr} + \beta \ln \text{pH} + \beta n \ln X * \ln X + \beta n \ln X * \ln Z + \varepsilon$$

Equation 1

where Y = is the annual total plot output of maize (kg/ha), L = the size of the plot measured by GPS device, Lab = is labor (family and hired workers in person-days/ha), Fb = is basal fertilizer (kg/ha), Ftd = is top dressing fertilizer (kg/ha), Hr = is the amount of herbicide (Kg/ha), St = is striga incidence (%), SoStr = is soil structure defined by the interaction of exchangeable sodium percentage (ESP) and silt, pH = is soil pH, ln X*ln X = are quadratic terms of all explanatory variables, ln X*ln Z = are the interactions of all explanatory variables, βi = are the parameters to be estimated (i = 0, 1, 2, 3), and ε = is the composed error term.

The explanatory variables included are the standard determinants of yield in agriculture productivity, with additions of specific soil and weed aspects. All hectare-based variables are computed using GPS recorded size, instead of the self-reported estimates. In the model, fertilizers components (N, P, and K) were not disaggregated since only minor differences in specifications are available in the market. In Ghana, the total area planted with maize hybrids is only 3% of the total area (Ragasa et al., 2013). Therefore, it was considered the use of certified seeds[5], which may or may not be hybrid. Only 7% of the surveyed farmers used certified seeds. We could, however, not include the data on the use of certified seeds because of collinearity problems with the use of agro-inputs. To ensure the rigor of the study, we controlled for site-specific field characteristics, one of them being the infestation rate of striga, as the parasitic weed is one of the major constraints to maize yields in the savanna zone (Lagoke et al., 1991). Plot-specific soil properties derived from the lab analysis were used in addition, information elicited from the respondents, e.g. on farming experience and extension service. First, a regression was computed only based on the input variables (Table 2/A); second, the analysis was repeated by adding soil parameters (Table 2/B). Finally, socioeconomic variables were added (Table 2/C). We correct for heteroskedasticity by clustering standard errors at community level.

[5] On a separate note, we have conducted a DNA finger printing test of improved maize seeds bought from agro-input suppliers in Ghana. The results (not yet published) show high genetic heterogeneity and about 11% of the samples is not relatable to the variety they are sold for. This indicates that farmers in Ghana do not have access to improved genetic material of good quality.

As the proportion of sample farmers who did not apply fertilizer was close to 20%, we followed the method developed by Battese (1997) and kept the input amount at zero for the non-users even after log-linearizing the model. A dummy variable was included to capture the difference between the farmers who apply fertilizer and those who do not. This method enabled us to use the full data set without dropping non-fertilizer users when input amounts were log-linearized. The data of farmers applying fertilizer may be useful in the estimation of parameters which are common to all farmers. Furthermore, the removal of the non-users would also bias the estimation of the parameters of the translog function.

For example, the dummy variable for basal fertilizer application is calculated as follows:

DFb =1 if Fb=0

DFb=0 if Fb>0

We created a basal fertilizer application dummy (DFb) and repeated the same procedure for other variables such as 'basal fertilizer', 'herbicide' and 'striga'. The final production function therefore is:

$$lnY = \beta 0 + \beta 1 \ln L + \beta 2\, lnLab + \beta 3 \ln Fb + \beta 4\, DFb + \beta 4 \ln Ftd + \beta 5\, DFtd + \beta 6 \ln Hr + \beta 7 DHr + \beta\, 8 \ln St + \beta 9\, DSt + \beta 10\, SoStr + \beta 11 pH + \varepsilon$$

Equation 2

Multicollinearity between basal and top dressing fertilizer application as well as between CEC and Ca^{2+} and between Mg^{2+} and K^{+} did not allow for the inclusion of all parameters. From these three sets of variables, we chose to include K^{+} because it is among the most important nutrients affecting maize growth and yield; Ca^{2+} was included in the function since it had a higher prediction rate. N also had to be dropped because of high correlation with C content.
We acknowledge that the regression model can produce biased results as farmers' decision on the use of inputs is likely to be jointly determined. To address possible endogeneity problems, we tested different instrumental variables (IVs): distance from household to the farm; distance to the input dealers; price of fertilizer transport from market to the farm; price of maize transport to the market; and lastly fertilizer price paid by the household. None of these instruments or combinations of instruments proved to be valid according to the F-statistic test results. This implies that the results have to be interpreted as correlations.

A Tobit model was used to examine factors affecting farmers' decisions on the intensity of fertilizer use. The model was chosen because of the high prevalence of farmers who used zero fertilizer (20%) and because it accounts for the qualitative difference between zero and nonzero observations (Wooldridge, 2010). We clustered standard errors at community level.

To capture the profitability of the fertilizer use, the computed Value Cost Ratio (VCR) was used, which is the ratio of the value of additional output (calculated as average response rate times the maize price, based on the farm gate price) to the cost of fertilizer. Profitability of fertilizer use is crucial to determine the fertilizer application rate (Jayne et al., 2018; Rashid et al., 2013).
The VCR is calculated as below:

$$VCR = \frac{Y(F) * Mprice}{F * Fprice}$$

Equation 3

Where F = average mineral fertilizer application rate (kg/ha)
Y(F) = average maize yield response to fertilizer at F rate (kg/ha)
Mprice = average kg price of maize (from household survey)
Fprice = average kg price of mineral fertilizer (at shop)
Average farm gate data from the survey, instead of country data was used, which present high variations due to, e.g. different levels of market access. Furthermore, the VCR was calculated both for fertilizer price with and without subsidy.

2.4 Results

In the following, table 1 presents descriptive statistics of the socio-economic data and the soil properties.

Table 1: Farmers and plot characteristics

Variable	Mean	SD	Min	Max
Number of observations	300			
Household characteristics				
Household head % of male	81			
Household size	15			
Years of farming experience	23.4	14.8	2	70
% ownership of a subsidy card	16			
% access to subsidy even without owning a card	19			
Total land owned (ha)	14.8	12.4	1	64
% of households that own a donkey cart	8			
% of households that could afford other inputs	39			
Service				
% of households that received extension in the last year	53			
% of households that received credit last year	16			
Plot characteristics				
Size (ha)	1.9	2	1	23
% of plots on which fertilizer is applied	81			
Amount of basal fertilizer applied (kg/ha)	95.5	92	0	476
Distance between plots and home (km)	3.6	4.7	0.003	36.5
Total labor (person-days/ha)	102.8	81.3	12	556
Striga incidence (%)	22.6	16.7	0	80
Maize yield (kg/ha)	1474	1171	71	6171
Plot management				
% of plots on which improved seeds were used	7			
Weeding times	1.3	0.6	0	2
Plot soil characteristics				
Number of observation	290			
Total C (kg/m^2)	1.3	0.5	0.0	4.1
ESP (Exchangeable Sodium Percentage)	0.7	0.8	0.0	8.0
pH	5.5	0.4	4.1	7.1
Exchangeable K^+ (kg/m^2)	15.9	8.5	0.0	76.3
Exchangeable Ca^{2+} (kg/m^2)	159.2	128.0	0.0	1751.5
Silt (%)	60.3	15.1	19.0	95.6

2.4.1 Determinants of maize yield and profitability of fertilizer

Results from the translog (table 2/A) show that an increase in labor has a positive and significant correlation with maize yield. One percent increase of basal fertilizer is correlated with an increase in maize output by 0.77 percentage points, ceteris paribus. The regression also shows a negative and significant correlation between the severity of weed incidence and maize yield. When adding soil properties (table 2/B), the above variables do not change significantly. However, the interaction variable of ESP and the proportion of silt particles in the sample ratio is significant, highlighting the importance of soil structure for overall maize production. The regression results identify fertilizer as the main lever, but also identify other factors that contribute significantly to determining yield.

In table 2/C, socio-economic factors are added. Fertilizer and soil structure remain significant whereas striga is not contributing any more to explain output, because weeding is included. The latter is also true for access to the extension service, whereas gender and weeding frequency significantly correlate with maize yield variance. Due to potential endogeneity, the interpretation of the results must be treated with caution. Still, the results are important as they provide important clues to the challenges that farmers in the study region face.

To roughly estimate the profitability of applying fertilizer for maize production, we computed the VCR, as explained above. The result of a VCR of 0.8 with subsidy and a VCR of 0.7 without subsidy indicate that fertilizer application is not profitable at current prices and current yield response rates, even if fertilizer is subsidized.

Table 2: Determinants of maize yield (kg/ha)

VARIABLES	Translog production function A (dydx)	Translog production function with soil variables B (dydx)	OLS regression with soil and management variables C
ln_plotsize	-0.082 (0.056)	-0.090 (0.065)	-0.107 (0.067)
ln_labour (person-days/ha)	0.167** (0.062)	0.205** (0.070)	0.245*** (0.065)
ln_BasalFrtlzr (kg/ha)	0.767*** (0.137)	0.808*** (0.131)	0.746*** (0.116)
D0_BasalFrtlzr (dummy)	3.141** (1.334)	3.779** (1.362)	3.390** (1.174)
ln_Agrochemicals (L/ha)	0.148** (0.056)	0.120** (0.048)	0.108** (0.047)
D0 Agrochemicals (dummy)	0.138 (0.116)	0.116 (0.108)	0.175 (0.108)
ln_Sriga (%)	-0.089* (0.049)	-0.081* (0.045)	-0.061 (0.043)
D0 Sriga_prcnt (dummy)	0.575 (0.436)	0.803* (0.417)	0.950* (0.447)
ln_C (kg/m^2)		0.089 (0.097)	0.038 (0.104)
ln_pH		0.618 (0.573)	0.456 (0.576)
ln_K (kg/m^2)		-0.0566 (0.077)	-0.039 (0.076)
ln_Ca (kg/m^2)		-0.157 (0.120)	-0.109 (0.117)
Soil structure (ln_ESP x ln_Silt)		-0.122** (0.051)	-0.121** (0.053)
Years_farming			0.003 (0.003)
Gender_farmer (dummy1female)			-0.064 (0.066)
Weeding times			0.130** (0.046)
Extension service (dummy)			0.055 (0.052)
Observations	300	290	290
Adj R-squared	0.644	0.669	0.681

Note: ***,**,* indicate significant differences at α=0.1, α=0.05, and α=0.01 respectively.
The interactions of all explanatory variables are included in Model A and B, but not reported.

2.4.2 Determinants of fertilizer application rates

The Tobit regression (table 3) shows that a farmer's access to a subsidy card is associated with higher fertilizer application rates. The same is true for wealth-related variables. The ability to purchase other inputs and the ownership of a donkey cart is, associated with higher fertilizer application rates, ceteris paribus. The same is true for smaller plot sizes, which corresponds to the results in the OLS.

Striga was considered, because higher fertilizer application rates reduce infestation severity (Ahonsi et al., 2002; Gacheru and Rao, 2001). Moreover, higher weed pressure generally indicates more degraded soil, which under the system practiced by the farmers will soon be left fallow.

Table 3: Estimates of total fertilizer application rates (Tobit)

Dependent	Coef.	Robust Std. Err.
Ownership of subsidy card (dummy)	56.83**	(22.79)
Gender (1 if female)	-14.48	(16.66)
Credit (dummy)	5.89	(18.96)
Use of other inputs (dummy)	28.28	(20.23)
Ownership of a donkey cart (dummy)	77.14**	(34.43)
Years farming	-0.81	(0.64)
Extension service (dummy)	-8.20	(20.94)
Plot size measured by GPS	-7.82**	(3.19)
Weeding times	13.34	(12.85)
Severity of striga (%)	-0.63	(0.60)
Distance HH to field (km)	-4.07	(2.61)
Distance community input dealer (km)	-0.06	(2.84)
Observations	300	

Note: ***,**,* indicate significant differences at α=0.1, α=0.05, and α=0.01 respectively.
District dummies included, but not reported.

2.4.3 Results from qualitative research methods

The focus group discussions and the key informant interviews revealed insights on the governance issues related to the FSP. The results indicate a lack of awareness of the FSP as well as a subliminal fear of authorities and ministries officials, who are in charge of administering the program. Farmers reported that they were hesitant to make requests as their concerns were not addressed and they were rather treated with scorn. In general, government officials are respected and, due to social norms, are not to be confronted. In all locations, transparency regarding the modalities to obtain a fertilizer subsidy card was lacking, affecting

trust in the authorities. Farmers reported that visits by authorities were unannounced, which made them miss the opportunity to participate. It also happened that farmers were asked to pay a fee to be registered or they were told that no cards were available for them, without further explanation. In other instances, officers would not issue a card as they claimed a family member already owns one and they should share it. Farmers were also asked to use the amount left from the previous year. In the latter examples, the amount of subsidized fertilizer per farmer and cropping season was substantially reduced and long-term planning compromised. Overall, farmers perceived the benefits of owning the card not worth the challenge they had to go through to obtain it. It is also notable that only 2% of the subsidy card owners were female household heads. The focus group discussions indicate that female farmers are the most neglected group by the program, as they were the least aware of the program's operational structure. It can be derived from the focus group discussions that large-scale farmers, who have more influential positions (mainly in the district capitals), receive fertilizer not only at a subsidized rate but also in larger amounts than foreseen by the program. This information was confirmed in the key informant interviews with representatives of local institutions.

2.4.4 Quality assessment of commercially available fertilizers

Fertilizer quality is a crucial to determinant to maize productivity. The analyzed sample was overall homogeneous and of good appearance. The laboratory testing confirmed that the labels described the nutrient contents of the fertilizers correctly (table 4).

Table 4: Results from mineral fertilizer testing according to brand

Brand	n samples	Mean N missing	Std. Dev.	% missing	Mean P missing	Std. Dev.	% missing	Mean K missing	Std. Dev.	% missing
A	25	0.3	(0.4)	1.2	1.1	(1.0)	11.4	0.8	(1.2)	15.7
B	22	1.9	(1.2)	8.3	-0.1	(1.0)	-1.3	0.8	(2.5)	8.0
C	10	-1.0	(2.3)	-6.8	1.4	(2.7)	9.0	1.2	(2.6)	8.1
D	18	0.3	(1.4)	1.3	0.0	(2.3)	-0.4	-0.2	(2.3)	-3.8
E	6	-0.3	(1.1)	-1.3	-0.6	(0.4)	-6.1	0.5	(0.4)	5.2
F	19	0.9	(1.0)	3.4	1.3	(0.5)	12.7	0.8	(0.4)	8.5

Note: Missing refers to the difference between the nutrient content reported on the label and the measured one

The deviating values cannot be attributed to adulteration since up to 7% can be caused by lab handling and the additional missing amount in some of the samples could be caused by storage and transport. Fertilizer samples were collected both from 50 kg bags as well as smaller bags, which are repackaged at the shops to increase input access. The analysis showed no difference in quality between original and smaller bags, even though repackaging provides an opportunity for adulteration. However, the price of the smaller packages was 20 to 80 % higher, which affects poor farmers.

2.4.5 Discrepancies between self-reported and GPS measures plot sizes

The empirically measured field data show that discrepancy between GPS-measured and self-reported field sizes increases with field sizes (tables 5 and 6). Overall, the size of 95% of the fields was overestimated. On the average, the reported size was 36% higher than the GPS-measured size.

Table 5: Summary statistics at plot level

	No. Plots	Unit	Mean	Std. Dev.	Min	Max
GPS	300 (100%)	Hectares	1.8	2.0	0.1	22.9
Self-Reported	300 (100%)	Hectares	4.5	4.4	0.5	37.0
Positive discrepancy: GPS>Self-reported	286 (95.3%)	Hectares	2.8	3.0	0.1	19.4
Negative discrepancy: GPS<Self-reported	10 (3.3%)	Hectares	-0.76	0.9	-0.01	-2.7
No discrepancy	4 (1.3%)	Hectares	0.0	0.0	0.0	0.0

Table 6: Discrepancies between self-reported and GPS measured plot sizes

Plot size (Hectares)	No. Plots	Mean plot area using GPS	Mean plot area self-reported	Plot Discrepancy (Self-reported GPS)	Discrepancy in %
0.01-1	101 (33.6%)	0.6	2.3	+ 1.7	25.7
1.1-2	104 (34.7%)	1.3	3.7	+ 2.4	36.2
2.1-5	80 (26.7%)	2.9	6.2	+ 3.3	46.8
<5.1	15 (5%)	8.9	17.5	+ 8.6	50.8
Average	300 (100%)	1.9	4.6	+ 2.7	36.2

2.5 Discussion

This paper contributes to the debate on the determinants to maize productivity in the Guinea savanna. To identify the levers that can be employed to address the persisting maize yield gap we addressed the issue from different angles, which are discussed in the following.

2.5.1 Striga is a neglected but important predictor in maize yield

Striga species are parasitic weeds that largely depend on a host plant to obtain their nutrients and water. Several studies highlighted the negative effect of striga in the Guinea savanna, specifically in Niger (Weber et al., 1995), Togo (Vogt et al., 1991), and Ghana (Albert and Runge-Metzger, 1995; Sauerborn et al., 2003).

In this study's focus group discussions, farmers identified striga as major determinant of yield. The quantitative results also show a significant negative effect. However, the magnitude of the effect is rather low (table 2). The main reason is that the marginal effects were calculated based on the average weed pressure of 20%, which is rather low. Striga is a significant negative predictor of maize yield across all models, but expectedly the analysis shows that, the negative effect of striga on maize yield can be reduced by weeding, herbicide and fertilizer applications (table 2/C). This finding confirms previous results on herbicide application (Abdulai et al., 2006) and on high doses of nitrogen application (Gacheru and Rao, 2001). Other practices to effectively control striga include the adoption of striga tolerant or resistant varieties; fertilizer timing (Di Tomaso, 1995); and intercropping and rotation with soybeans (Groote et al., 2010).

2.5.2 Soil properties are significant yield determinants

The role of nonmarket factors, such as soil fertility, has not been extensively addressed in earlier studies on fertilizer programs, but a better understanding of this dimension may lead to innovations that fit the needs of small-scale farmers (Braimoh and Vlek, 2006). Physical properties, such as soil structure, are as important as chemical properties in determining soil fertility. Labile soil structure had a significant negative effect on yield in the present study, which can be attributed to the dominance of silt-sized particles and result in a high vulnerability to mechanical stress. Furthermore, with increasing ESP the vulnerability of clay and silt to disperse and aggregates to collapse is increasing. Data suggest that this is the case for the analyzed plots, though ESP values were rather low: 0.7±0.8 % (maximum: 8.0 %). Overall the interaction of ESP with the silt fraction significantly affects soil structure and ultimately yield (table 2). Poor structured soils are vulnerable for structure deterioration upon mechanical stress, such as raindrop splash and tillage. The consequences can be serious for crop growth: Soil pores can block, surface sealing by crusts (Nelson and Oades, 1998), lower infiltration rates, higher surface runoff and soil erosion as well as lower root penetration, reduced seedling emergence and aeration can take place (Amézketa, 1999; Bronick and Lal, 2005; Schweizer et al., 2017). Shainberg and Levy (1992) found ESP values of 2.2 to cause 70% drop of the final infiltration rate of clay-rich soils. ESP values below 4% were found to have negative effects on aggregate stability (Ben-Hur et al., 1985; Lado et al., 2004; Levy and Torrento, 1995).

Soil organic matter has an overall positive effect on chemical and structural soil properties; an effective measure to improve soil structure is to increase soil organic carbon (SOC) by increasing organic inputs (e.g. manure and compost) and reduce losses from erosion and decomposition (Akoto-Danso et al 2018; Häring et al., 2013; Häring et al., 2017; Nelson and Oades, 1998). Further, mulching is recommended to reduce vulnerability of surface crusting by raindrop splash and erosion. However, only a small body of literature included soil variables when determining fertilizer application profitability, with very interesting findings. Kenyan farmers for example, profit from fertilizer application if their fields have at least 3% of soil carbon (Marenya and Barrett, 2009). Depending on the location, other soil properties can be crucial, as in Zambia under acidic soil conditions, phosphoric fertilizers were found to be unprofitable (Burke et al., 2017). To address low productivity, it requires substantial investment in technical know-how (Groote et al., 2010).

2.5.3 The potential of fertilizer application remains underutilized

The literature has focused on policies and the role of the private sector in Sub-Saharan Africa to explain low fertilizer use. Results show, even with increasing private sector participation, fertilizer use at plot level remains too low to ensure food supply, taking into account continuous losses in soil fertility (Crawford et al., 2006; Morris et al., 2007; Poulton et al., 2006). Enabling farmers to achieve higher yields through profitable fertilizers application is expected to increase the demand for inputs. However, current input and output prices do not suggest that a sustainable demand for fertilizer will emerge. Still, incentivizing higher fertilizer application using subsidies has remained a particularly popular policy instrument to increase yield. In this study, fertilizer use was associated with higher maize yields (table 2). This was expected since maize has high nitrogen (N) requirements and nitrogen deficiency is a major cause of low yield. Ragasa and Chapoto (2017) show that farmers in northern Ghana are further away from applying the optimal fertilizer rate as compared to farmers in the south. Simulation studies found that the availability of fertilizer in small packages of five kg or less will increase both adoption and use intensity (Freeman and Omiti, 2003). In Ghana, smaller packages are available at a 20-80% higher price per kg compared to the full bag. Resource-poor farmers, who are not able to purchase an entire bag, are most disadvantaged by this pricing policy. The main purpose of the FSP is to support smallholder farmers. However, the evidence collected in this study, in line with previous findings, suggests that the program is, by and large, not reaching the target group. Fertilizer and yield output prices differ substantially across the country due to differences in access to infrastructure and markets, which has a substantial impact on transport costs and price information. Therefore, especially in remote areas, farmers have low bargaining power and are dependent on farm gate sells. At subsidized prices and assuming perfect implementation of the FSP, the rough estimation of fertilizer profitability, value cost ratio, is on average only 0.8. The calculation of the VCR with fertilizer prices without subsidy, is of 0.7. The standard interpretation is that VCR values greater than 1 indicate that farmers increase their income by using fertilizer. This interpretation does, however, not take the risks associated with fertilizer use into account. Some authors suggest a threshold of a VCR of 2 or more to accommodate price and climatic fluctuations, which could then lead to a sustainable demand for fertilizer by smallholders

(Crawford and Kelly, 2002). Our results on VCR clearly show that at the current fertilizer and maize prices, a sustained demand for fertilizer will not emerge. The VCR values calculated in this study differ greatly from the rate of (at least) 2.6 found by Ragasa and Chapoto (2017). The divergence may be attributed to two major differences. The study by Ragasa and Chapoto (2017) is based on aggregated data from the entire country, whereas this study focuses the northern Ghana, which is suffering from harsh climatic conditions and poor infrastructure. Secondly, data for their study was collected from the end of 2012 ending and the beginning of 2013. Since then, the high depreciation rate has increased fertilizer price by 57% from 39 Ghana Cedi in 2012 to 89 Cedi in 2015 (Barrett and Sheahan, 2017). Furthermore, this study corrects for the plot overestimation, which means that labor productivity, as well as other inputs, are likely to be underestimated elsewhere. As researchers have raised doubts on the accuracy of soil quality perceptions by farmers and existing soil maps, another major difference, is a higher accuracy of plot-specific soil parameters that was achieved in this study.

In conclusion, this study confirms that increased fertilizer use has the potential to benefit farmers by contributing to increased yields, but at current prices, fertilizer use is not profitable. Bringing down fertilizer prices to increase profitability is an option that has been widely discussed in literature. Other options include infrastructure projects that are connecting remote areas to markets. In the communities included in this study, many farmers are dependent on traders coming to the community and they have therefore, very low bargaining power.

2.5.4 Fertilizer subsidy cards increase fertilizer utilization

Different FSP implementation strategies have been adopted in Ghana, e.g., vouchers and a direct subsidy. The current subsidy card is seen as a new “smart” instrument to address shortcomings of the earlier methods. The efforts of the program are reflected in the results of the Tobit model: Ownership of the subsidy card (which applied to 16% of the surveyed farmers) was associated with a higher fertilizer application rate. Nevertheless, the program also has its challenges. During the focus group discussions, farmers reported problems in gaining access to the card. As a result, two farmers share one card, which increases the percentage of farmers who have access to subsidized fertilizer to 19%, but reduces the amount of fertilizer per card user. Farmers in communities located closer to larger towns are registered through their mobile phones as an alternative to the physical subsidy card. However, very few farmers own a phone and they were generally dissatisfied with this option. Despite the program’s aim to target smallholder farmers, the share of farmers who own a card (or, alternatively, are registered through the mobile phone’s SMS system) is alarmingly low. This finding is consistent with the results of Houssou and collegues (2017), who found that in 2011, 78% of the subsidy benefits went to unintended beneficiaries and only 17% of the recipients were poor. In the present study, the distance between the homestead and the field is associated with lower fertilizer application rates, which is likely related to labor and transport costs. This finding is in line with other studies, which found that transaction costs rise with distance to input markets and are a major limiting factor to fertilizer application and application rates (Martey et al., 2013; Minten et al., 2013; Zhou et al., 2010). This study

confirms results found in the literature (Mwangi, 1996) that major constraints to achieving higher fertilizer application rates include non-price factors such as fertilizer availability and market information that raise shadow prices. Only few farmers own a card, but for those 16%, the effect on fertilizer use and maize productivity is positive, controlling for other factors.

2.5.5 Governance challenges limit the effectiveness of the FSP

The focus group discussions provided additional information on the challenges farmers have faced when accessing the FSP and clarified the reasons behind the participants' choices. The challenges are manifold, but lack of information turned out to be a major problem: It was unclear to most farmers (i) whether the FSP will be implemented in the given year; (ii) when it will be implemented; (iii) who is eligible for the fertilizer subsidy card; (iv) what the modalities to receive a card are and whether it is free of charge; and (v) what amount of subsidies each farmer is entitled to every year. The focus group discussions indicate that poor targeting of the program and related problems of elite capture and rent-seeking are undermining the purpose of the program. Extension agents were in charge of giving out the fertilizer subsidy card. One of the problem found it in the literature is that they have no verifiable standard method to identify the actual target group of smallholders (Houssou et al., 2017). This problem is consistent with the results of the Tobit model in the present study: a household's wealth variables (donkey carts and the use of other inputs) were significantly associated with access to a subsidy card. Additionally, card holders still faced the problem that subsidized fertilizer was not always available when needed and in the quantity foreseen by the FSP. This finding echoes other studies, which also identified distribution problems and availability at the retailers as major constraints preventing farmers from applying the recommended fertilizer rates (Freeman and Omiti, 2003; Low and Waddington, 1991; Morris et al., 2000; Smale et al., 2011). The literature also supports the perception of the focus group discussion participants that elite capture is a major challenge of the program. In the Northern region, Imoru (2015) found that network connections and influence were important factors influencing the participation in the FSP. Similarly, Jatoe (2016) states that large-scale farmers had not only better access to the subsidies, they were also able to acquire amounts far beyond the amount foreseen in the subsidy program. In spite of these governance challenges, fertilizer subsidy programs remain an attractive policy to attract media and voters' attention, especially during election times (Birner and Resnick, 2010; Jayne and Rashid, 2013).

2.5.6 Fertilizer content reflects labeling on packages

Fertilizer supply is confronted with governance challenges arising from asymmetric information: For the farmer, it is difficult to assess the quality of fertilizer at the time of purchase, which creates incentives to supply sub-standard products, thus making fertilizer a potential "lemon technology" (Bold et al., 2010). The need to assess fertilizer quality has been well established in previous studies, which identified low-quality or fake fertilizer in Nigeria (Liverpool-Tasie et al., 2010), Uganda (Bold et al., 2017) and China (Khor and Zeller, 2014). The variability in fertilizer's quality can also lead to bias in the estimates of production functions (Khor and Zeller, 2014). In the present study, fertilizer quality problems could not be identified. The lab analysis confirmed that the fertilizer labels reflected the actual nutrient

contents. Therefore we assume participation in the FSP and fertilizer application rates are, in our case, not related to low fertilizer quality. During the focus group discussions, fertilizer quality was never mentioned, and when asked, farmers confirmed their trust in the quality. However, most farmers lacked general knowledge on formulations and application modes, e.g., between NPK, sulfate of ammonia and urea. Farmers indicated that they tend to choose fertilizers based on price and availability rather than nutrient content. Overall, fertilizer application rates were on the average 145 kg/ha, corresponding to 30 kg/ha N (if we consider an average of 20% N content). These rates are lower than the 56 kg/ha N found by Ragasa and Chapoto (2017) in the same study region.

2.5.7 More attention needs to be paid to field measurements

The data used in this study are based on GPS measurements, as explained above. Accurate measurement of plot sizes is obviously important for studies that deal with crop productivity since any measurement bias will inevitably affect all results. From the data, we can infer that yields and fertilizer application rates based on self-reported values are overestimated. Considering that most economic studies on crop productivity in Sub-Saharan Africa rely on farmers' self-reported plot size data and taking into account that the average overestimation of the plot sizes found in this study was 36%, we can deduct that "real" application rates and yields are considerably higher than those currently reported in the literature. Since the discrepancy was found to be increasing with increasing plot sizes, "real" input and output rates are weighted higher in larger plots. This finding also has implications for the discussion regarding the inverse relationship between land size and productivity (Byiringiro and Reardon, 1996; Kimhi, 2006). Overall, the findings indicate that the data collection effort required for GPS measurements of plot sizes seems well justified in studies dealing with agricultural productivity.

2.6 Conclusion

The goal of this study was to contribute to the debate on yield gaps and fertilizer subsidy programs in Sub-Saharan Africa by using different data sources that have in earlier research on this topic not been combined in one study: data from a household survey and from focus group interviews; lab-based analyses of soil and fertilizer samples; GPS measurements of plot sizes; and data on striga infestation collected with the help of pictures. The findings confirm the concern arising from earlier studies that fertilizer subsidy programs have limited effect if they are not combined with a more comprehensive approach to address site-specific agronomic problems that lead to low crop productivity. The analysis throws light on two challenges that deserve specific attention: One is soil structure, which was found to be a significant factor contributing to low crop yields in the case under consideration. Extension services could address this problem by making recommendations on improved soil organic matter and integrated soil fertility management, e.g. by mulching and applying organic fertilizer, such as manure and compost. Moreover, soil testing as a part of an extension "toolkit" and rapid, cost-efficient lab analysis at national level are approaches that could be worth investing in. The other challenge is weed control, which is often a problem in non-

mechanized smallholder households, because mechanical weed control is labor-intensive whereas agro-chemical control involves monetary expenses and requires capacity building to ensure appropriate application and avoid health hazards.

The findings also have methodological implications for future studies on crop productivity: First, the results show that relying on farmers' information instead of taking GPS measurements of plot sizes can lead to a considerable bias in crop productivity parameters. Hence, the additional effort to collect these data may well be justified. Second, the study highlights the advantages of combining socio-economic with bio-physical data in order to arrive at a deeper understanding of the underlying factors of low yield response to fertilizers, which has hampered the effectiveness of fertilizer subsidy programs.

The findings also add to the literature on the governance challenges of fertilizer subsidy programs. In this regard, the combination of data collected from surveys, focus groups and lab analyses proved valuable, as well. The data showed that fertilizer quality was not a problem in this case, whereas studies on other African countries had identified problems in this regard. The findings also indicate that the use of subsidy cards did not resolve targeting challenges, as the programs favored larger farmers. The study revealed another challenge, which is often neglected. Poor and especially female farmers rely on small fertilizer packages, which are offered at agro-input shops at substantially higher prices per unit. Smallholders may purchase in groups to address this problem. Overall, the study findings suggest that the reallocation of government expenditures for providing training on locally tailored agronomic practices can be expected to have a higher impact on yield and food security than just subsidizing fertilizer.

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Chapter 3

The myth of the Market Queens: A case study of women and power in Ghanaian markets

Lilli Scheiterle and Regina Birner

Abstract

Markets in Ghana are largely managed by women traders organized into groups according to commodity, often referred to as "market queens" (MQ). In the public perception and limited literature, MQ have a negative connotation and are described as "cartel" and "mafia" institutions. This study aims to investigate: 1) the nuances of these female-led institutions 2) the structure and function of the associations, and 3) their perception outside the market. Using a qualitative research approach, a theoretical sampling technique was applied and in-depth interviews with MQ and traders in the entire country were conducted to empirically assess their role in the market. Expert interviews with public and private sector stakeholders complemented the data. Our findings show that MQ are leaders of an association nominated into power either by existing traditional leaders or market traders. Market associations are vital for women that rely on trading as they offer saving, insurance and credit services. They represent a crucial link to producers and are decisive to guarantee food availability and stability, especially for urban consumers. The structure varies between ethnic groups and commodities. As a minority they are an easy target and held responsible for high prices and economic challenges. Contrary to current literature, our results reveal that MQ do not leverage their power to set market prices, but instead provide an important informal safety net. Market women are perceived as powerful; nevertheless they are neglected in gender and value chain literature. These empirical findings challenge the negative representation of MQ and highlight the need to recognize market women organizations as collective action and credit groups, which are crucial in the value chain. We apply Foucault's concept of a political economy of the will to knowledge to explain why a negative discourse about the MQs prevail and why research has not challenged the negative discourse, so far.

Key words: Market queens, traders, female led-organizations, power, Ghana.

Hans-Ruthenberg-Institute, Social and Institutional Change in Agricultural Development, Wollgrasweg 43, 70599 Stuttgart, Germany

3.1 Introduction

In development-oriented literature on gender, women are often portrayed as social beings who are deprived of any power, whose rights are suppressed and whose role is constrained by rigid social norms. This framing is particularly widespread in the literature that deals with rural women in low-income countries and it cuts across disciplines. In the economics literature, intra-household bargaining models have provided a powerful rationale of why women are in a disadvantaged position (Folbre, 1986). Consequently, the need for strategies to empower women is widely emphasized in the development literature. This literature has its merits which can hardly be overestimated. Without any doubt, discrimination against women is widespread across societies, and many studies have shown that empowering women is not only a goal in its own right, but also has a positive impact on rural development and equity and on the nutritional status of the family (Goldstein and Christopher, 2005; Johnson et al., 2016; Quisumbing and Pandolfelli, 2010; Udry, 1996).

Yet, the discourse that portrays rural women as essentially suppressed social beings who need to be empowered, most notably by development interventions, has left a "blind spot" in the development literature. Are there no spaces in developing societies where rural women play powerful roles without having been empowered by some type of intervention? Are they all inherently suppressed unless they belong to social elites or benefit from empowerment efforts? And if spaces exist where rural women traditionally exercise power, why has the gender-oriented development literature paid so little attention to this question? Is there not a lot to learn from situations in which women have traditionally been able to exercise power, even in societies where discrimination against women is widespread?

In this paper, we search for answers to these questions by conducting a study of "market queens" in Ghana. The term "market queen" is used in the Ghanaian society for female traders. Market queens play an important role in markets for agricultural products. They may be in charge of a particular agricultural commodity or groups of commodities, as for example plantain traders association is led by the 'bordiee hemaa' (plantain queen mother). "The label of the "queen" points to a position of traditional power. Therefore, the institution of the market queen (hereafter MQ for brevity) appears suitable to address the above questions. Studies on the institution of MQ that are based on sound empirical research using either quantitative or qualitative methods are surprisingly scarce. And – interestingly – the scarce literature that does exist on MQs portrays them as almost exclusively in a negative way. An example is (Banful, 1998:155) who claims that "the current marketing system appears to be satisfactory but it is suggested that the role of MQ or middle women needs to be abolished to reduce retail price". Likewise, Katila (1997:284) writes that the institution of the MQ "operates like a cartel and like all cartels presents an impediment to the efficient functioning of the market mechanism". There is surprisingly little scientific evidence to support any of these statements. The prevailing negative undertone in literature reflects widely held perceptions in Ghanaian society about MQs, but it rarely based on scientific inquiry. Contributing to closing this knowledge gap is main aim of this study. Our study, which is based on 68 interviews held in 42 markets in all regions of Ghana, reveals that MQs are the generally democratically elected leaders of traditional self-help associations of female traders

that operate in rural markets. Though there are marked differences between the roles of these associations between the North and the South of Ghana, they play in both parts of the country important roles in the organization of such markets, such as providing for dispute resolution and acting as a social safety net for the traders. These associations enable traders are act as an essential link in the value chain enhancing food availability and stability and, therefore, contributing to food and nutrition security in rural and urban areas. These findings are in stark contrast to the prevailing negative perceptions about the MQs. In light of our findings, this paper also aims to analyze why the current literature has either neglected the institution of the MQ or portrayed it in an overwhelmingly negative way. In Section 3.6.3 , we suggest that the "political economy of a will to knowledge" (Foucault, 1978) may help to explain this phenomenon.

3.2 Insights from the literature on trade and markets in developing societies

The majority of the available literature on market institutions in Ghana is either specific to commodity traders or considers female traders as a homogenous group. These studies focus on two main cities, namely Accra and Kumasi, located in Southern Ghana. The relatively scant literature leads to generalizations and assumptions, that fuel deeply rooted perceptions of the general public. The country extends over six agro-ecological zones; it comprises of 44 ethnicities and has many languages with a vast portfolio of cultural system of behaviors and practices. Societal organizations are reflected in different aspects of daily life as well as in the economic activities, for example in the market. Additionally, the intrinsic features of the commodities influence the trader's organizations.

3.2.1 The perception of the middleman

The simplified concept of the middleman, trader or intermediary is used in the marketing literature to denote an actor that functions as a link between producer and consumer. The literature recognizes the importance of the middleman in the value or supply chain, but often in an antagonistic role to its counterparts. The proposition is that they take a large share of the profit margin, limiting upgrading opportunities for actors that rely on their service (e.g. Lee et al., 2012).

The fact that they are perceived negatively is not new to traders; the concept of middlemen minorities or ethnic market-dominant minorities is discussed in literature. Amy Chua (2002) describes trading minorities in many contexts across continents and how politicians used them to gain political power, making them "scapegoats" to divert the attention from deteriorating economic conditions. Historically, middlemen minorities are found in almost every society; Chinese throughout Southeast Asia, Persians in India, Igbos in Nigeria, Indians in East Africa, Lebanese in West Africa, and the European example of the discrimination against Jewish traders, which reached a peak in World War II. Common to these minorities is that despite the discrimination they were able to gain prosperity and were able to access quality education and become the most successful ethnic group in society. Politicians targeted these minorities to raise their power (which has been successful, see Hitler in Germany, Mugabe in Zimbabwe,

Milosevic in Serbia) and therefore were and are victims of violence, repression and racialist programs (Chua, 2002).

Women traders are common in African countries and face similar discrimination to the ethnic market dominated minorities. Nevertheless, to the best of our knowledge, little evidence based data is available which explain the negative reputation. Minorities described by Chua (2002), have rather little contact with the dominating population and are increasingly becoming wealthy, and become prestigious members of society; in contrast, market women in Ghana belong to the same prevailing ethnic community in the region and are not visibly accumulating savings or increasing their wealth.

3.2.2 History of conflicts in the market

The reputation of market women controlling quantity and prices of the commodities sold in the market is deeply rooted in the perception of consumers and government officials. Claire Robertson (1993) studies class formation and the socioeconomic history of Ga women in Accra. With the imposition of colonialism in 1874, political power was taken from men and women, forcing men into labor intensive activities and women elders to focus on trading opportunities that allowed for middle women to assert their independence from male elders. In Accra, the capital of the new colony from 1877, men received education and were enrolled into an apprenticeship system, finding jobs in petty administration as carpenters or in churches. Women's political power was completely ignored by the colonialists and lost any authority. Women got out of production and farming and gained independence through trading and depended on it. Clark (1994) states that the formation of female led commodity organization was consequent of a vacuum created by the removal of the chiefly offices and before the colonial power established their ruling parties. With the establishment of the commodity wholesale yard and the formalization of the commodity groups between 1930 and 1950 the role of the group leader, queen, was institutionalized. The dissatisfaction with the Nkrumah (1960–1966) administration on local and international policies, especially the restriction on importsi and wage cuts, led to urban food shortage and price rises (Mikell, 1986). Market women were made responsible for rising consumer prices and good shortages since the 1960s [6] (Schindler, 2010). The urban unrest and the political dissatisfaction led to the coup d'état in 1978 and the first Rawlings' coup in 1979. However, the new ruling government did not implement policies to revitalize the rural areas that traditionally produced the revenue for the country, rather kept blaming market traders, particularly women, for driving up prices and instigating the economic crisis. During this time women in trading risked going out of business, they suffered confiscations of their goods, public punishment and beatings, and total economic failure (Schindler, 2010). Market women were used as scapegoats to divert the attention from the deteriorating economic conditions and out of the

[6] The challenges at the farm level forced women to migrate to urban centers where they got involved in trading. Markets in the urban centers became crowded and trades negotiated and protested for more space and stalls. In Koforidua, a powerful but isolated event took place; market women succeed in a food boycott in 1977 in response to the local authority's harassment and restrictions of food prices (Campbell, 1985).

fear of government of the erosion of its political base.[7] The exposure of the traders and the importance of the food items they were trading made them a powerful target (Campbell, 1985).

Nationwide during 1979 and 1982, markets were set on fire. In 1979 an explosive was planted in the Makola market of Accra, in 1982 Tamale Central Market was completely burned down. These politicized mobs were encouraged by soldiers and caused the disruption of trading activities for several years (Schindler, 2010). Not only the market women suffered loss of their properties, the cash they used to store in the stalls, but the economic drawback drove many families into extreme poverty (Amoako-Tuffour, 2007; Schindler, 2010). These same female traders play a crucial role in provisioning food items from the hinterland into the market and guarantee food supply to urban populations, and actually "stood between a near failed state and famine in the late 1970s and 1980s" (Amoako-Tuffour, 2007).

Tensions between the formal authorities and market traders occasionally arose in Ghanaians major markets. In 1997, angry market women protested the sudden over-night 100% increases of tolls and stall rents in the street of Kumasi [8] (KIT and IIRR, 2008).

In 2007, government officials met in Accra at the 58th Annual New Year School to consult on how to increase the revenue base of the district assemblies. The consensus during the meeting was that MQ undermined the "free market economy" and represented a burden to toll collectors in the market. In conclusion, officials were encouraged to exert their authority and make use of the Local Government Act 462 of 1993, which conferred them more power to control markets and the collection of revenue in the municipal, metropolitan and district assemblies (Amoako-Tuffour, 2007). The harassment of market women continues to be upheld and encouraged in the mindset of local officials through such interventions. The press continues to report interviews with government officials, and institution representatives which maintain the stereotype that market women are holding a monopoly over the sources of supply and are determining prices (CUTS, 2016). Even todays gender mainstreaming has not positively impacted the discourse on female traders.

3.2.3 Tomato traders in Ghana

A relatively small number of documents are available on market associations in Ghana, mainly focusing on tomato traders (Adimabuno, 2010; Amikuzuno and von Cramon-Taubadel, 2012; Robinson and Kolavalli, 2010). For this particular commodity, MQ are itinerant traders, the direct link between the production site in the hinterlands and the urban consumption area, defined as 'tomato queens'. Tomato women's associations are found be highly powerful institutions and are referred to as 'cartels' or 'mafia' groups in the cities of

[7] "Market women, because of their visible role, were forced to bear the brunt of public displeasure provoked by shortages in goods, invisible inflation, decline in terms of trade, corruption, and incompetence" (Robertson, 1983:469).

[8] The mayor of the city had not included them in decisions that concerned the market and threated them disrespectfully on other occasions whereas other informal associations as the shoe makers and drivers were taken serious and threated respectfully (KIT and IIRR, 2008).

Kumasi and Accra (Adimabuno, 2010; Katila, 1997; Ngeleza and Robinson, 2011; Robinson and Kolavalli, 2010). The transportation of this highly perishable and delicate vegetable from the extreme north of the country towards the south on poor roads comes with considerable transaction costs and risks. The trading networks are strong and provide traders a specific weekday on which they can travel to the farms. This system, to some extent, regulates the amount of tomatoes in the market and avoids losses of the produce and lowers the risk for traders. Price differentials are particularly prominent in the high bumper season when prices should be lower, but instead remain at same level during the entire season (Adimabuno, 2010; Amikuzuno and von Cramon-Taubadel, 2012; Robinson and Kolavalli, 2010). In contrast to other crops, tomatoes are not produced in the demanded amount in the hinterland of the major cities; irrigation systems are required whereas staple foods are generally less affected by handling and by the rough transport conditions. Even if accounting for the risks encountered by the traders (e.g. robberies, extortion, loss of the produce through accidents, no credit repayment from farmers) the prices in Accra exceed the financial risk taken by the traders purchasing the tomatoes from the Upper East region (Adimabuno, 2010; Amikuzuno and von Cramon-Taubadel, 2012; Katila, 1997).

3.2.4 Women and trade in Africa

Female traders dominate markets in many African and Latin American countries. This is linked with the prevailing lower access to land and education that limits their access to resources, financial services and to formal employment. The work at the market allows for certain flexibility, such as child care, purchasing of groceries and preparation of meals contemporaneous to the trading activity (Akinboade, 2005). The work at the market involves interaction mainly with women and is therefore considered as an appropriate activity according to religious and local norms (Babb, 1998; Robertson, 1993).

Female traders are common in the African context, their role and reputation differs based on location, ethnic affinity and cultural context. In Nigeria, Hausa, Yoruba and Igbo women are expected to provide for their personal items, in some parts also contribute with food products and come up with their own means to take care of social contacts, as part of their tasks. Additionally, according to social norms, women need an occupation to be respected as adults (Makinwa-Adebusoye, 1994). Traders are motivated to enter the business through female family members because of economic and cultural values attached to the trade (Yusuff, 2013), and through success in trade, women achieve an elite status (Ejikeme, 2011). In the North among the Kanuri there is a gender component in the types of commodities traded (Porter 1995), which is reflected in the findings from Mali (Harts-Broekhuis and Verkoren, 1987). Kanuri women are selling lower value local products whereas men are engaged in more expensive categories of goods such as cola nuts and livestock. However, the gained independence is perceived as dangerous and indeed, underpinned by the high rate of divorce among Kanuri women involved in textile trading (Porter, 1995). Prominent in Benin and Togo are female textile traders known as “Nana Benz”, who gained exclusive rights to trade European goods in particular wax print with European firms, and made Lomé the center of textile distribution (Prag, 2013; Sylvanus, 2013). In the Mina language or Guin “nana” means mother or grandmother, expressing courtesy and respect for their social position, were as

"benz" describes their business success that enabled them to afford a Mercedes Benz in the 1970-80s (Toulabor, 2012). In the mid-1970s the economic power of the Nana Benzes in Benin was supported by the political leadership that provided them import licenses, low turnover and export taxes, in return they publicly supported the ruling party and were even appointed political offices. This favorable trading condition contributed to the formation of oligopolistic market associations that strengthened their economic and political power. Nevertheless, the changing political and trade environment affected the dynamics also in the informal sector, and the trader's power was redistributed. The Nanettes are the successors of these once very powerful traders that today assert themselves through personal networking in the neoliberal textile market (Prag, 2013).

In Nairobi, Kikuyu and Kamba, women trade as a survival strategy to meet their families' basic needs. Despite their vital function to provide goods to urban dwellers, Robertson (1997:264) in a chronological description of events affecting traders writes "once again the markets, dominated by Kikuyu traders, were viewed as seats for disaffection and sedition, and hawkers as an unruly population needing repression". Cross-border traders in the Great Lakes region are comparatively important to make goods available at affordable prices between countries, nevertheless they are subject to violence or harassment during their movements, and they are charged unofficial duties and prohibitive tariffs. Generally they hold a very negative perception and are treated like "smugglers" rather than with the respect of a business woman (Brenton et al., 2011). Similar cross border traders from Zimbabwe were accused of witchcraft, prostitution, smuggling all sorts of wares and held responsible of carrying the much-needed foreign currency out of the country thereby labeled as "unpatriotic economic saboteurs" and generating an image of "inhuman and grotesque money-grabbers" (Muzvidziwa, 2001:68). This strategy served the politicians, business people and government officials to divert the attention from their activities as real responsible for the foreign currency consumption (Cheater, 1998). As illegitimate "smugglers" they are treated as an anomalous group that is greedy and lazy and needs direction to acquire skills for a "proper" occupation and trough public denunciation and shame can be brought under control (Cheater, 1998; Muzvidziwa, 2001). Despite all accusations and media attacks, cross border trade grew and the establishment of associations across national boundaries led to the success of female entrepreneurs (Muzvidziwa, 2001).

3.2.5 Traders in the "Moral Economy"

The literature on the "moral economy" provides further insights into the organization of trade and markets in developing societies. In a moral economy, reciprocity and redistribution are the principle behaviors that ensure economic order rather than the profit motive; remunerated work and the principle of least effort are lacking (Polanyi, 1944). In this approach the economy is an "expression and extension of what society is doing, that is, the mutual commitment of its members to each other through the exchange of goods and services within the family and through networks of dependency" (Fassin 2009:1240). Moreover, the moral component of the concept implies norms and obligations, which define what is and what is not done. It is led by judgments and actions not based on economic principles but on good behavior and norms. Principles of good character, justice, dignity and respect, are norms that

a moral economy is based on (Fassin, 2009; Polanyi, 1944). In a small community the prices might be determined by a moral economy, where prices of subsistence crops are made by use value rather than of exchange value. Outside the village the forces are different, demand is anonymous and prices fluctuate. The trader dilemma arises when the trader on one hand is expected to pay a fair price to the farmer and at the same time has to sell at local, national or world market prices. The trader is expected, due to moral obligations, to offer the commodities at an affordable price, but if she is too generous and extends credit she might faces losses and bankruptcy. If she doesn't, her behavior is considered amoral, she finds herself in a dilemma, the difficult choice between two unfavorable courses of action (Evers and Schrader, 1994). Small-scale subsistence trade plays a crucial role and it is important to distinguish between the heterogenic populations of traders in the market, e.g. traders in which vending is the only source of income and those who diversify their livelihood strategies and vending is either a regular or occasional activity. In the case of traders who differ in their social characteristics of the community they live in, it is consider easier for them to operate outside the prevailing social norms (Southworld-Llewellyn, 1994). Nevertheless, it is argued, "the moral economy sphere has been sustained with personal economic asceticism and restrictions on private wealth through charitable contributions" (Evers, Pavadarayan, and Schrader 1994:205).

3.3 Methods

3.3.1 Research design and data collection

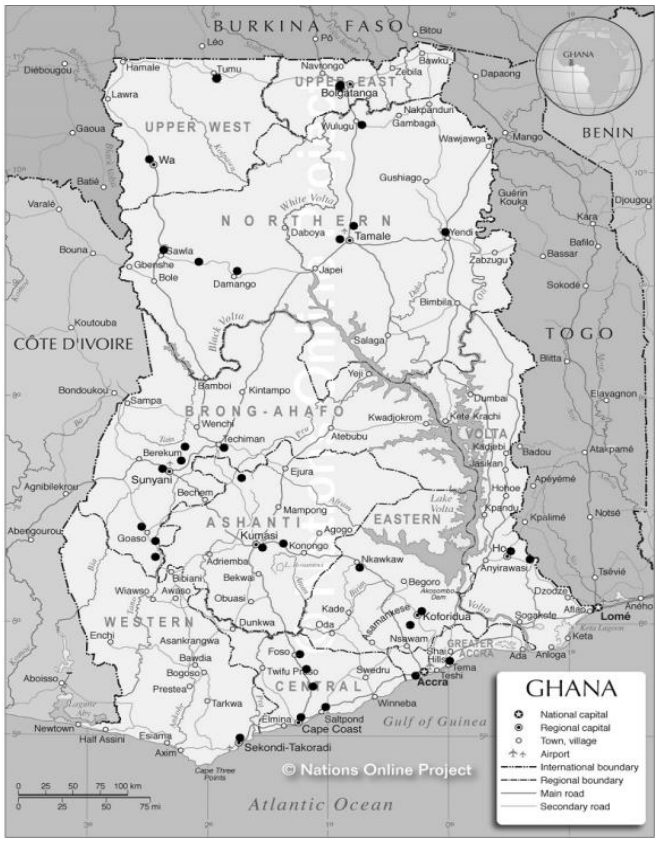

Figure 4: Map of markets included in the study
- **Location of markets visited**

Empirical data for this study was collected through a field study conducted for seven month during two periods between September 2015 and 2016 in all ten regions of Ghana. The markets visited included regional (10), district capitals (22) and community markets (9). Larger cities have more markets; therefore the total number of markets visited was 38.

A qualitative research approach was adopted for this study. To gain insights into the behavioral perception, action, and values in the complex context of the research, we applied a combination of research methods: (i) literature-based study; (ii) direct and participant observations. This method enabled

a richer understanding on the complexity of the daily market life, captured better the function of existing networks and gained insight into the views on the matters discussed with participants. (iii) In-depth interviews following an interview guide were conducted in order to gain insights into the market associations and in the dynamics that govern traders associations.

The selection of interviewees was done through purposeful sampling, determined by: (i) Commodity sold. The traders interviewed were selling cassava, plantain and maize in the South and dried fish, yam and maize in the North. Maize is common nationwide, cassava and yam represented the prevalent starchy stable crops in the south and in the north respectively, and plantain and fish were chosen because of their importance in the regional diet. (ii) The role they have in the market network. The data was collected from market traders and market traders with leadership function (when available); Additional informants (traders) in the market were selected by snowball sampling (see Biernacki and Waldorf, 1981:141). The inclusion of additional traders in the interview process was determined by the concept of theoretical saturation described in Grounded Theory (see Corbin and Strauss, 2008), based on this, when no new information emerges, and redundant information prevails, the process can be concluded in the particular area.

At the markets, a formal introduction by local civil authorities that granted their research permission preceded the interviews. To avoid deception the purpose of the study was explained to the respondents and consent was sought from the market authorities in advance. All respondents shared the information voluntarily for the study. The subject discussed covered mainly market activities, function and responsibilities of traders in the group, and features and roles of the group leader. Nevertheless, the flexible interview guideline enabled us to capture rich and detailed qualitative data without requiring prolonged interviews with participants (Shabbir and Di Gregorio, 1996). The researchers assured confidentiality of the information shared and the in-depth interviews allowed researchers to gain insights into sensitive and personal topics. With this method, 68 in-depth interviews were conducted (table 8) with durations between 45 minutes to 1.5 hours. Only six interviews were held in English, the majority was translated from the regional language into English. The interviews were recorded and transcribed; this paper is based on the analysis of the original interviews as core of the empirical data.

Table 7: Overview on interviews conducted by type of market and function of traders

	Regional/District capitals		**Communities**	**Total**
	Daily market	**Weekly market**		
Total markets	21	11	9	**42**
Market leader	12	-	8	20
Commodity leader	14	9	-	23
Trader	11	8	6	25
Total Traders	37	17	14	**68**

Experts for the interviews were identified among research and government institutions, which work at different stages of the value chain of the chosen products. The snowball sampling technique was utilized here and resulted in 9 expert interviews.

By using qualitative methods it was possible to disclose features on the market association structure and their network, which are difficult to reveal with other methods. Moreover, this empirical technique allowed accounting for difficult to measure variables, such as social standing, reputation and trust. The presented empirical findings are not considered statistically significant in a narrow sense, but aim to shed light on indigenous market institutions that are not fully understood but, play an important role for female traders and contribute to food security and the functioning of the value chain.

3.3.2 Data analysis

Data analysis was done through a multistage approach. Initially, the recorded interviews and data were organized, transcribed, cleared and labeled. Recurrent themes were identified, as well as patterns in the data. Respondents were clustered. The data was searched for answers to the research questions. For the purpose of classification, summarization and tabulation, a content analysis was carried out. For this latter approach, the main instrument used was the formation of codes and categories (Cresswell, 2007:152). By review and interpretation of the code-category-relations, data was summarized under larger category themes by combining subcategories, which developed by arranging and grouping coded themes (Merriam, 2009).

3.3.3 Validation

To ensure the quality of the information collected, member checks were performed. The data and the interpretation of it were continuously tested during the interviews by paraphrasing in clear and simple wording, summarizing for clarification, with the respondents. For triangulation purposes, key informant interviews with the researchers and personnel from the Ministry of Food and Agriculture (MoFA) and from research institutions in Accra, Kumasi and Tamale were conducted. The information was tested against the available literature to ensure the quality of the data. Furthermore, peer debriefing was carried out during several occasions at the university and at the international Tropentag conference in Vienna in 2016, where the findings were presented and discussed. The combination of different collection and quality testing approaches compensated for limitations of the single methods (Brewer and Hunter, 1989; Guba, 1981).

3.4 Results

Female traders dominate markets across Ghana; the relatively few male sellers are dealing with high value commodities such as livestock and fresh meat, and north cola nuts in the north (used for ceremonies and gifts). Trading is a risky activity, on the one hand because of the investment in perishable products, and on the other due to the challenges encountered during transportation such as breakdowns, accidents, robberies, extortion, and in the worst case, death.

3.4.1 Variations of the organizations between markets

Similar commodities come with comparable risks, are purchased under similar conditions and face equivalent constrains. Exchange of information becomes especially valuable because of these characteristics. Therefore, it is reasonable that market women form groups according to the type of commodity sold. In smaller markets, commodities would also be grouped according to similar characteristics. For example, plantain, cocoyam and cassava were sometimes sold by the same trader; the same is true for rice and maize or beans and groundnuts.

It is important to consider that markets differ between rural and urban areas and within the urban setting. Differences are in size, schedule and in terms of sellers typologies.

Daily markets are located in town centers, in this construct traders are constant, basic infrastructure such as stalls, public toilets and waste collection systems are available. For this service, traders need to pay a toll.

Furthermore, in urban areas a ‘weekly’ market that operates regularly, on a 3 to 8 days basis is common. These markets are located at the outskirts of towns; here different groups of traders and consumers come together: farmers that sell directly, wholesalers and long distance traders that fill up their trucks, chop bar owners, private consumers, as well as the traders from the daily market that purchase part of their supply. These markets represent a very dynamic and well-attended platform and due to the direct interaction with producers prices are lower.

Market traders’ associations are based on trust and personal interactions, among “full-time” traders in both typologies of markets. Groups of female traders in weekly markets have organized their activities and follow a common schedule.

3.4.2 Variation of the organization between regions

The functions and norms prevailing in the associations reflect the ethnical context in which they are operating. Our findings show a remarkable difference between the structure and the aim of the market traders associations of the Akan dominated south and the Dagomba dominated north of the county.

To provide quantitative information of the themes mentioned by the traders, bases for the analysis, table 8 shows the frequencies a theme was mentioned and because of the regional and ethnical differences, respondents were divided by location.

Table 8: Frequency of themes mentioned by respondents during the interviews

Themes	% of respondents who mentioned theme	
	Traders in the south (37 respondents)	Traders in the north (31 respondents)
Qualities of the organization leader		
Good character	86%	71%
Good rhetoric skills	73%	39%
Families trading history	32%	84%
Well connected in the community, with other traders and farmers	95%	61%
Social status/wealth	38%	90%
Functions of the leader		
Link between the market and the traditional and government authorities	100%	71%
Coordinate the markets activities	100%	90%
Enforce contractual arrangements	92%	81%
Preside disputes	100%	87%
Functions of the group		
Insurance against adverse events	59%	90%
Protection towards opportunistic behavior	73%	74%
Financial support for funerals	95%	81%
Access lending and saving facility	27%	100%

All markets visited in the south, are headed by the 'market queen', the point of reference for all traders. Larger urban areas have various female-led associations that organize according to commodities sold, led by 'queens'; economically less prominent commodities are grouped under one 'queen'. The wording is borrowed from the *Akan* tradition, of matrilineal kinship, where chief and the queen mother are in charge of the overall community, look after its wellbeing, and chose the new king from her lineage. As are the market women, known as 'queens' because of their responsibility for groups of sellers. Traders are organized into associations, based on the main commodity they sell. Each association is coordinated by women known as 'Queen' and depending on the commodity they deal in; they take the name of the product. For example '*bankye* or *banyere hemaa*' is the definition of the leader of the tubers sellers association (cassava or yam queen mother).

The MQs are responsible for anything that happens to the traders of the group she is leading. In case of an emergency, such as a trader having to be taken to a hospital, the commodity leader would be responsible until a family member arrives. She also needs to mediate and solve disputes between traders and the formal and informal authorities, and maintain the reputation of the entire group and herself.

Patrilineal kinship communities, mainly Dagombas, dominate societies in the north and a larger portion of the population is Muslim. In all sites in the northern part of the country, the associations are characterized by greater commercial orientation and operate as microcredit or saving groups for women in the market. Widely adopted by the traders are the rotating savings and credit associations (ROSCAs) and the peer-to-peer banking and peer-to-peer lending systems. The groups are organized around the commodity sold and are led by the commodity leader or chief so called magajia. The wealth of the commodity leader was considered a reason to nominate her into office, to show respect for her status, and because of her privileged position, local authorities are keener to accept her position, which is an advantage for the entire group.

In the text we refer to queen, magajia and leader interchangeably.

3.4.3 The Market Organization and Role of the Leaders

MQs were not found to be commodity specific in small markets (district or community level) but, the coordinating agent for the entire market, whereas in very large markets (larger districts and regional capitals), one of the commodity queens also takes up this second function. The MQ differs from the commodity leaders; she is the link between the authorities and the commodity queens, and the contact person for matters concerning the entire market population.

In all larger markets, sellers organize into groups depending on the commodity sold. An elected member heads the associations. In even bigger cities, with more groups selling the same commodities, sellers join the group based on ethnicity. Trader's access fee is between 5 and 30 GHC (1 and 7.5USD), in small communities there is no charge. The participation in the group secures access to the safety net of the association as well as from reduced transaction costs for transport and information. She has to comply with the rules, contribute when others are in need and be aware that failing any of these responsibilities can lead to her exclusion from the group. Among the markets visited, the group sizes did not exceed 50 members, mainly because trust and personal relationships are the most valuable assets to traders. Across all visited markets, the group leader is an important centralizing and coordinating agent in the complex market network. The respect and authority given by social norms and the recognition of her office is crucial for the smooth running of the market business. Anyone is eligible for the position but recurring trades and features were identified by the respondents that a queen or leader should have. Paramount is the character.

"*The queen should be someone with a good character, she should not love to fight but, have strength to settle disputes and talk well in public*" (Plantain trader in Goaso, 2015)

"She [the queen], should be trading for long in the market, be experienced and have a good character" (Cassava trader in Sunyani, 2015)

"The queen should be the one that can provide plantain in very time of the year, even if there is no plantain in the market" (Plantain trader in Kumasi, 2015)

All interviewees agreed that the leader should be trustworthy, committed to the market activities and skilled in money handling. She is required to know the market business well,

have good bargaining skills and be firm in her decisions. Her mild character is considered by the member of strategic importance to smooth down differences without attracting attention. Consumers will be reluctant to purchase from a woman or a group known for her ease to start disputes, therefore it is in the interest of the queen to settle disputes quickly.

A recurring feature of the leader in all interviews conducted was the long (family) experiences in trading and good network to other traders, and to local and government authorities are an advantage. Good rhetoric skills are highly appreciated by the members since she will represent the entire group during official meetings, local festivities and celebrations but she can also lobby for the space in the market or better facilities for her group with the traditional authorities or the district assembly, all respondents mentioned this. Her social status is an advantage for the entire group, it will facilitate her lobbying work and it carries the responsibility for all members to perform their best to keep the reputation high.

In the north, due to the financial orientation of the organization, the leader is also chosen based on her economic status. Here, wealthier women were elected in this office because of their personal ability to give loans to their peers. This feature was not found to be a priority in the south.

The elected queen or leader will be in office until her death, when she is not able to come to the market because of the advanced age she would delegate her responsibilities, often to a family member in trading. After her death, a new leader is elected into office. In the case the chosen person is not considered to have the adequate abilities to represent the group, members will call for reelection; this was equally mentioned in markets in the south and in the north. In some instances, the queen would then be presented to the chief, mainly there where the chieftaincy is still strong and the royal family resides in town. In rare cases the chief himself would select the MQ he wants to correspond with, this was found only in two very traditional locations.

The associations have a hierarchical structure. In some cases (eleven), the structure is well defined and even formalized with vice, a secretary and a treasurer, in other cases it is more lose. Generally, the members are elected in the individual positions by other members and will be active until resignation or death. In some exceptional cases (five), secretaries or treasurers were found to be male, because of literacy.

In all cases, the queens were found to be the link between both traditional and government authorities, as well as between the traders. Notifications of changes in the market infrastructure as well as communication of events and celebrations pass from the queen to the members. The leader is expected to attend celebrations as well as traditional and customary events, as she represents the traders and an important institution in the market and society.

All interviewees confirmed that all members meet to discuss problems in the market, challenges and to improve their marketing techniques. They also discuss problems related to the market infrastructure, such as accessibility to the wholesale yard, sanitation problems, and storage and waste management issues, which are then brought up during meetings with local authorities. Meetings among group members were rather irregular in the southern regions whereas in the north some groups (four), were very strict; participants were even fined for not

attending meetings without excuse or for coming late. The fine was kept in a common savings pot and used for group purposes. Due to the higher degree of financial orientation among these groups, the administration of the contributions was also a prominent topic.

At all markets visited, the leaders preside over disputes and enforce contractual arrangements between the agents in the market. For the parties, accepting the queens' decision is the cheapest way of enforcing a contract. Involving local authorities such as the police, the chief or even the court would come with high transaction costs for all involved parties. A good leader is respected by all parties through her ability to negotiate with farmers and retailers alike.

At all study sites, the respondents emphasized the queens function to settle quarrels, ensure the smooth running of the trading process and be the link between the traditional and the governmental authorities. The settlement of disputes is one of the most times consuming of the daily queen activities. Quarrels arise between farmers and traders, amongst traders, and between traders and customers on loan repayment issues, quality perceptions and non-respected agreements. Disputes also arise between the market fee collectors of the district assembly. The fees are collected every day in the south and only a few times a year (irregularly) in the north, for the maintenance of the market space. The trader's reputation to be a fair bargainer and a person "*who does not love to fight*" (cassava trader Sunyani, 2015) is important for the efficiency of her business.

"*Being the queen is a honor (laugh)… but it is also a big burden and you need someone, you see my daughter here, she is here every day, as a queen you are called everywhere in the market, all the time, and who runs your business? (laugh)…There is no benefit… only the respect*" (Commodity queen Koforidua, 2015).

This last statement was emphasized in most interviews. The office is a sign of prestige and respect, and some acknowledged that they have a better bargaining position with wholesalers because the latter wants to keep a good relation to the queen and avoid frictions, which overall does not contribute to their income. Holding the office was often described as more of a burden because of the time consuming activities involved (e.g. mediating, attending functions and meetings) at the expenses of trading itself.

At smaller markets, where farmers sell directly, the relation between farmers and traders is crucial for both sides in different seasons. The farmer wants to keep a good relation with the traders to have an outlet for his produce during bumper harvest of his crops, and the trader will keep on buying because she wants the farmer to sell to her in the low season of the crop, when there is a shortage. Being able to provide goods in low season enhances her reputation of being a good trader of that particular commodity. It is a form of trust and reliability between the actors in the value chain, but it also highlights the need for strong relationships and networks. In general the queen does have a strong network, also to other commodity leaders in other locations; this provides information on prices and quantities in the production areas. This information is passed over to the group members that will adjust their bargaining with itinerant traders and wholesalers.

Traders stressed that the participation in a commodity group is a form of insurance of the single members. The active contribution in the group is a guarantee for support in times of need. Members support each other through hard times due to robberies, loss of the acquired produce due to breakdowns during transportation and/or other unforeseeable shocks such as hospital bills and funerals. In the northern part of the country, the associations collected the weekly contributions or after the trading day and took them to a common bank account. The savings can be lent to a member to restart her business after a shock or to make an investment. Repayment modalities depend on the groups' arrangements. Eighty percent of the groups stated they share the commonly accumulated amount plus the interests among the members, only 20% stated to let the amount sit in the bank even above a year until someone is in needs for it. The access to the informal savings and credit sources is of vital importance in the risky business of trade and for traders with small capital and no collateral to access this kind of service.

Across regions and ethnicities, funerals are considered a hardship; being a member of a group allows access to support. Weddings are also a financial burden for the families but are not unexpected events; therefore they are not considered reasons to access the groups' safety net.

Funerals are generally of high social and customary importance, in the south (Akan dominated area) they are meant to celebrate the life of the deceased and disclose the status of a family. It involves high costs and (often) leaves the families in debt. Funerals are a social event at which number of mourners attending reflects the social status. Part of these huge costs is to be paid in advance and all family members are meant to contribute, neighbors and friends would give their donations and contribute to the expenses as well. Funerals are also reasons for group members to raise funds in the north, even though the *dagomba* adopted prevalently Muslim customs in this regard, and funerals are much less of a social event and representative for the social status of the family. However, they also represent a financial shock since funerals have to take place within three days, putting financial pressure on the relatives.

The presence of the MQ or commodity leader at funerals is of high social value for the families, since it reflects the social status and their importance; this was found to be the case among all regions.

3.4.4 Perception of traders organizations and the MQ

The opinions of the government representatives and researchers interviewed were generally aligned and reflect what can be found in the local news. Market traders are pictured as greedy and powerful, described as heartless businesswomen that take advantage of their strategic position at the expense of farmers and consumers. The MQs are seen as the sole decider on market related issues, "the cartel" institution that puts up entry barriers for new traders and forces farmers to sell at a loss. A more accurate description of her role, her way of acting, differences at local or commodity level, market internal structures were unknown. „*MQ decide on the price of plantains in the market and are allowed to pick one plantain from each seller and sell at their stall. They have a lot of power*" (interview government employee, Accra, 2015).

3.5 Discussion

This study captures the different market typologies, focusing on locally important commodities, other than tomatoes, and with the ambition to give a multifaceted picture of trader organizations and their leaders in the entire country. Highly debated is the role of MQ as cartels. The results from this study did not find evidence of a cartel like structure. MQs are the representatives of female trader groups; the participation in the group enables access to a safety net, as well as to information including prices and quantities in other cities. Despite the narrow knowledge of local media and the general public, the negative perception and strong opinions are found at the agriculture and market related institutions. Therefore, shedding light on the market institutions would foster the potential for producers, consumers and policy makers to develop an efficiently functioning market environment.

3.5.1 Organizations Function and Role of the Leader

The gender literature has focused on intra-household relations emphasizing the importance of education, assets stewardship, and female empowerment of women and its effect on food security, child health, education and contraceptive use (Allendorf, 2007; Doss, 1996; Hashemi et al., 1996; Jejeebhoy, 2002; Quisumbing and Maluccio, 2000; Schuler et al., 1997; Thomas, 1990). Achieving poverty reduction and human rights are consider to be dependent on women's empowerment (Malhotra and Schuler, 2005; The World Bank and IFPRI, 2010). Several projects programs and NGO's have focused their work on addressing these inequalities, a popular intervention is the creation of female farmer groups to strengthen the position of the single member, with the aim to empower female farmers, and promote commercialization of the produce in a gender equitable way (Fischer and Qaim, 2012; Ogunlela and Mukhtar, 2009; Quisumbing and Pandolfelli, 2010). However, the efforts to support traders have been limited. Our results confirm that female market traders are still seen as economic saboteurs, Schindler (2010) shows how banks express their mistrust by rather low access to assistance of market women and initiatives to support traders are not notable. Trading activities at the smallest level enable the survival in the absence of a public social system, trading is a risky activity, and the formation of traders groups fill the gap of financial institutions and play a major role in developing countries (Zeller et al., 1997). The demand for credit from poor households is mainly to overcome shortfalls in food consumption through savings and insurance services as well as consumption credits, and less for production related expenses (Zeller et al., 1997). Women trader's organizations across Africa are known to form lobbies to influence the formal and informal authorities, but they are also vital for the transmission of information for the smooth functioning of the commodities value chain, as well as guarantees for credits and insurance (Baden, 1998). Access to credit increases the efficiency of capital allocation and allows for investment opportunities with high returns to the poorer segment of the population; additionally access to savings services has been shown to increase investments especially among female entrepreneurs (Dupas and Robinson, 2013). Its limitation has direct repercussion to the overall economy (Aterido et al., 2013). Still credit and extension programs are targeting men and seem to consider less the other half of the population and renounce to their potential clientele.

MQs are considered powerful, and depending upon the size of the market, the commodity traded and the market structure this can be explained by social norms and networks. In the city of Sunyani, a male trader tried for several days to sell a truck full of cabbage at a daily market. A few days later someone suggested that he go and see the queen who was encouraging the group members to make an effort to buy from the new trader. This incidence shows the role and the "power" of the hierarchical structure and on the social norm that play an important role. Lyon (2000) and Lyon and Porter(2009), analyzed the role of moral norms, trust and networks in the agricultural markets in Nigeria and Accra. Concluding that strongly enforced moral norms make competitors act as colleagues and do not let the market descend into chaos. The strength of an authority (e.g. queen or magajia) is based on common values, beliefs, tradition and on the recognition of the leadership, similar to the chieftaincy system. Norms can be enforced by sanctions, and norms determine which sanctions are acceptable. Petty traders and microenterprises in agricultural markets in Ghana rely on this value, especial due to the lack of formal legal institutions, other studies support this findings (Clark, 1994; Gore, 1978; Lyon, 2000).

The results show that transaction costs are high since small amounts are bought from a large number of farmers and sold in small amounts to a large number of customers. This is in line with other studies that found market organizations to be crucial to decrease transaction cost by facilitating access to transport and credit, settling disputes without the intervention of formal authorities and by providing channels for information and training (Fafchamps and Minten, 2001; Smith and Luttrell, 1994). Commodity queens are responsible for the smooth running of the transactions in the market, which in the past led to well documented politicization of the institution, used to divert, in times of economic shortages the attention, from underlying political and economic problems. This led to the public perception that MQs impose prices and even create artificial shortages in the market to control quantities was very widespread and repeatedly mentioned. In addition, this was most likely fueled by studies on tomato marketing and projected to all crops traded indistinctively. The protests in the past have shown that the traders have a sense of justice, values, and reasons that emerge as the threshold of tolerable exploitation is exceeded, as recognized in the moral economy. Protest arise when the economic as well as the subjective dimension is violated (Thompson, 1971).

The challenge of increasingly growing urban areas is linked with challenges in the providing food; it has proven that mature groups with functioning rules and activities based on natural or social capital are in the best position to improve the market situation (Salifu et al., 2010).

3.5.2 Factors determining differentiation

a. Commodities traded

There is a very small body of literature that describes the market associations, which trade products other than tomatoes. This work concentrates on market organization of regionally important commodities, such as tubers, plantains, maize and dried fish. These food crops are produced locally in backyards, can be transported in bulk, and have longer shelf lives. Tomatoes, on the other hand, need careful handling during the entire value chain, especially during transport; large quantities are transported in crates or baskets, with high risk of getting

damaged. Storage represents an issue in most markets, since there is no refrigeration and the available stalls are often overcrowded. Additionally, tomatoes are usually purchased far away from main urban centers, due to its high demand, an entire network has evolved around it, which is preventing new traders from entering the business and regulates the quantities of produce in Accra and Kumasi (Adimabuno, 2010; Amikuzuno and von Cramon-Taubadel, 2012; Wongnaa et al., 2014). The main markets in these two cities are busy; rather space constrained and need a certain degree of organization to guarantee a smooth supply of all items. In the available studies on tomato trade, queens are the itinerant traders, taking risk and baring the costs of traveling to the other end of the country, whereas in the case the analyzed commodities in this study, queens are the chairperson of a more or less structured group of retailers. The structure of tomato trader organizations is fairly well documented and the influence on prices has been acknowledged and assessed in the past (Adimabuno, 2010; Amikuzuno, 2009; Okali and Sumberg, 2012; Wongnaa et al., 2014). Drawing conclusions from the traders and the organization around one crop on the heterogenic landscape of commodities and markets seems overly simplistic.

b. Market Typologies

The study's' results highlight the different typologies of markets that coexist in the same urban centers and are a common feature throughout the country. The distinction between daily and weekly markets is important to analyze the cartel function of the trader organizations. In the outskirts of large cities, as well as in every other urban area, in addition to the daily market, a weekly market is taking place, open to consumers and traders. Traders among markets are very diverse and include wholesalers that purchase large quantities and sell to retailers, retailers that sell at their stall all week long, farmers selling directly, as well as farmers selling small quantities directly however, the boundaries between categories are blurry and the attempt to define them would lead to an "unending taxonomic exercise" (Campbell, 1985: 423). The heterogenic nature and dynamic population of these settings reveals that control over the quantities and prices introduced in the market are hardly possible. The main commodities traded in local markets are produced in the hinterlands; the amounts are difficult to control especially given the rich difference between traders and markets.

c. Regions, kinship and norms

From the results collected among all ten regions in Ghana it was possible to categorize trader organizations based on their regional and ethnical affiliation. Female trader organizations in the south of Ghana are imprinted by the dominating A*kan* societal structure. The community leadership system is based on gender parallelism and dual leadership of the chief and the queen mother. In practice, the chief takes political administrative decisions, including land tenure, supported by male elders. In the symbolic domain, the queen mother represents the mother of the clan and the mother of chief. This puts her gives her a special position in the overall sociopolitical system as she is respected as advisor to the chief (Odame, 2014; Okali, 1983). This structure is reflected to some extent in the market, the commodity queen is integrated in the market political system, she is in charge of the wellbeing of the group members and has an overall leading function supported by the members. The strong

bargaining skills such as the mild character and the ability to not react to provocations influence the election decision. The reputation of the group depends very much on the representativeness; the market institutions are backed by the community chief, who is involved only in market affairs if the queen cannot solve the issues alone. Nevertheless, dealing with higher authorities is not desirable since it seen as a failure of leadership.

In the *Akan* tradition, the stool owns the land and allocates it to individuals or for community purposes, as for example the market. The royal family formerly had market correspondents to collect food items from each trader for their consumption or for festivals, as a fee for the land. The commodity leader would gather the food items to be sent to the palace. This commitment is limited to festivals nowadays, but she still represents the link between the traditional authorities and the market traders. The power of going to the individual traders was backed by the chieftaincy and by existing social norms (personal communication).

Patrilineal ethnic groups dominate the north and a higher share of the population is Muslim, with an overall poor infrastructure and sparse population. This partly explains the stronger credit, savings, and insurance function of the trader groups; women, due to cultural norms, have less access to production factors and additionally face infrastructural and service-related challenges. Results have shown that the *magajia* is often a woman with a higher socio-economic status, which can support a single trader, in case the group cannot. The structure is tighter and attendance at meetings stricter, the absence or delay without a reason is in some cases fined. The sizes of the groups are smaller, and divided by ethnicity, which fosters a sense of unity, trust, and is based on the common understanding of norms and behavior (Fehr et al., 1997). The negative perception of the traders was not found to be embedded in the society; markets were less politicized in the past, and transition from urban areas to rural areas is smooth.

3.5.3 Perception

The results show how market women try to solve structural problems that arise when trying to make a living from trading, but at the same time are hitting the borders of social norms of solidarity and shared poverty. The affiliation to different ethnic groups solves "the trader's dilemma" by extracting traders from the moral obligations of the surrounding (Evers and Schrader, 1994). However, female traders in Ghana are neither socially nor ethnical different from the community in whose midst they live, one could argue that the creation of credit and saving institutions is partly allowing for their withdrawal from moral obligations. Despite little evidence, local authorities and the media demonize market women to be an obstacle (handicap) to the free market economy (CUTS, 2016, interviews with all government officials and researchers 2015 and 2016). The image of greedy and profit oriented traders that take advantage of their strategic position is deeply rooted in the perception of the general public [9]. This challenged the triangulation purpose of our interviews with local authorities.

[9] This was evident also during the presentation during the Tropentag conference in 2015 were a participant vehemently disapproved with the results, arguing that if the government and others institutions representatives were stating them to be a cartel, there was no reason to dough it.

Trade represents an opportunity for an additional source of income, and allows farmers to combine subsistence production with cash generating activities. An elaborated and heterogenic network keeps prices low (Korff, 1994) and a cartel function of the market organizations appears challenging, where there is no restriction to entry, no space limitation, and no full control over the commodities traded as in most of Ghanaian markets. Empirical studies, nevertheless, have found market groups acting as cartels in the case of tomatoes, because of it peculiar features, but a monopoly over prices and quantities of other commodities could not be confirmed through this work and other rigorous empirical findings in literature (Clark, 1994; Lyon, 2000; Mensah and Antoh, 2005).

These insights raise the question as to why a negative perception of the MQs persists not only in public perception, but also in the scientific literature. As indicated in the introduction, Foucault's concepts of power and discourse may help to explain this fact. In his work on "The Will to Knowledge", Foucault (1978) explains that the type of scientific evidence produced--or not produced--on a subject has a far-reaching influence on the discourse on this subject. Foucault recommends to analyze the strategies that are immanent in the will to knowledge and to examine the "political economy" of knowledge production (Foucault, 1978, p. 73). Foucault also draws attention to the issues that are not articulated in a discourse: "We must try to determine the different ways of not saying such things, how those who can and those who cannot speak of them are distributed, which type of discourse is authorized […]. There is not one, but many silences, and they are an integral part of the strategies that underlie and permeate discourses" (Foucault, 1978, p. 27).

Applying these considerations to our case, we can try to answer the questions: Why have researchers not invested more time and effort to find out what the role of the MQs actually is? Why have they just reproduced the negative public discourse about MQs rather than questioning this discourse? Considering Foucault's propositions on the relations between knowledge production, discourse and power, one can hypothesize that the negative discourse on the MQs may have several sources: One source could be a general negative perception of traders and middlemen (in this case middlewomen), which is widely documented in the sociological literature on trade and markets in developing societies, as explained in Chapter 2. Another source may be a disguised form of opposition that stems from the fact that the MQs and the associations that they represent have achieved a level of empowerment that is perceived to be a threat in a male-dominated society. The argument that MQs form a "cartel" or "mafia" is a discursive strategy that provides a rationale to abolish this institution, while discovering the positive role they play as elected leaders of self-help associations would undermine this discursive strategy. But why, if this is the case, have feminist researchers not developed the "will to know" what is behind this institution of the MQ and to challenge the discourse of the MQ as a form of cartel or mafia? The political economy of the will to knowledge may explain this fact as well. Females who are empowered based on their own collective action do not fit well into a feminist discourse that emphasizes, above all, the suppression of women in all spheres of society. Neither do they fit in the discourse of development organizations, which raise their funds by implementing projects that aim at empowering suppressed women.

3.6 Conclusion

This work contributes to a small number of analytical studies devoted to successful grassroots female institutions and aims to challenge the perception of female traders in Ghana who are seen as "mafia" or cartel like organizations concentrating power and profits in their hands. A large body of literature has focused on intra household gender roles, where women are generally power poor, but less is known about powerful female organizations and their structure. Shedding light on these female led groupings, revealed regional and differences between commodities traded, emphasizing how changing one of the variables can draw results that are no longer comparable. The focus of this work is on organizations are trading stables contributing to food security and highly appreciated commodities , both in large cities and in small to very small communities. Ethnicity determines association structure, the role of the queen in the south has an analogical role to the queen mother, she is responsible for the commodity group, perceived as very powerful, most probably because in the legacy of the dominating *Akan* kinship, and reinforced by studies focusing on tomatoes in space constrained markets as Kumasi and Accra.

Nevertheless, the formation of cartel institutions was not confirmed, due to the diverse traders populating the large varieties of markets even in the same urban agglomeration, and the variety of commodities sold. In the north, the institutions are of greater commercial orientation, based on rotating savings institutions, which enable women to access credit and savings even in infrastructure poor areas. However, throughout the country, market associations are important for women to engage in a risky activity.

In line with the considerations formulated in the introduction of this paper, we hope that this study has also thrown some light on a "blind spot" in the gender-oriented literature on development. While this literature has gone a long way to discover why and how rural women in developing societies are disadvantaged, there may be merit in paying more attention to strategies that women have been able to employ to empower themselves, even in societies characterized by rigid gender norms that disadvantage women. As in case of the MQs, those strategies of self-empowerment by collective action can be expected to be hidden from public view and confronted with an often aggressive negative discourse. As argued in this paper, the political economy of knowledge production may reinforce such a discourse. The task of emancipatory social science is to challenge it.

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Chapter 4

From commodity-based value chains to biomass-based value webs: the case of sugarcane in Brazil's bioeconomy

Lilli Scheiterle[1], Alina Ulmer[2], Regina Birner[1] and Andreas Pyka[2]

Abstract

The shift from a fossil-based to a bio-based economy (bioeconomy) requires more efficient utilization of the biomass generated from agricultural production. This can be achieved through the cascading use of biomass, which also offers the potential of creating additional value from biomass by developing novel products. Taking sugarcane as a case study example, this paper aims to analyze how well Brazil, the world's leader in sugarcane production, is positioned to reach these goals. The paper combines two conceptual tools: one is the 'biomass-based value web', which was developed as an extension of the value chain concept with the aim to capture the links within and between value chains that arise from the cascading and joined use of biomass. The other concept is that of the 'national innovation system' (NIS), which serves to identify the different types of actors involved in the biomass value web and the linkages between them. For empirical data collection, the study combined three methods: a mapping of the physical biomass flows in the value web, in-depth interviews with the actors involved, and the application of the 'Net-Map' tool to identify the actors in the NIS and their linkages. The findings show that the development of Brazil's international competitiveness in sugar and ethanol was based on political incentives that resulted in a strong network of institutions that focused on these two products. However, to become a front-runner in the future bioeconomy, the existing innovation network needs to be expanded. In particular, it is important to integrate national and international private sector organizations. The findings also suggest that industries need stronger incentives to collaborate with knowledge institutions. Long-term consistent policies and funding opportunities for risky investments are also required to further strengthen Brazil's innovation network to meet future opportunities and challenges of the bioeconomy.

Key words: Bioeconomy; Biomass value web; Innovation system; Brazil; Sugarcane.

[1] Hans-Ruthenberg-Institute, Social and Institutional Change in Agricultural Development, Wollgrasweg 43, 70599 Stuttgart, Germany

[2] Institute of Economics, University Hohenheim, Wollgrasweg 23, 70599 Stuttgart, Germany

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4.1 Introduction

In recent years, an increasing number of countries have decided to promote the development of a 'bioeconomy' and they have devised bioeconomy policies and strategies to reach this goal. An indication of this trend is the Global Bioeconomy Summit held in 2015 in Berlin, which brought together bioeconomy experts and stakeholders from more than 50 countries. The Communique of the Summit noted that there is no unified definition of the bioeconomy, but many share an understanding of "bioeconomy as the knowledge-based production and utilization of biological resources, innovative biological processes and principles to sustainably provide goods and services across all economic sectors" (Global Bioeconomy Summit, 2015, p. 4). Several driving forces account for the rising global interest in the bioeconomy. One is the urgent need to reduce greenhouse gas (GHG) emissions from fossil fuels by moving to renewable energy sources, which include biofuels (see, e.g. Pätäri et al., 2016). Another driving force is rapid progress in life sciences, which has yielded unexpected opportunities to create novel bio-based products and use biotechnological processes in a wide range of industries, including chemistry, healthcare and food processing (Global Bioeconomy Summit, 2015).

The bioeconomy is, however, not without challenges. As critics have pointed out, the move to a bioeconomy is not *per se* environmentally sustainable (see review by Pfau et al., 2014). Moreover, the increasing use of biomass may jeopardize global food security. Increased water use, not only for crop production, but also for processing of feedstock in biorefineries, may also lead to higher food prices and affect food security (Rosegrant et al., 2013). To address these concerns, there is now an increasing emphasis on ensuring sustainability in the bioeconomy. As the Communique of the Global Bioeconomy Summit (2015, p. 5) points out, it is "an important task to align the principles of a sustainable bioeconomy with those of a circular economy. This would involve systemic approaches across sectors (i.e. nexus thinking), particularly innovation policy measures that aim at optimizing Bioeconomy value networks and minimizing waste and losses."

This paper uses the case of sugarcane in Brazil to analyze the opportunities and challenges of applying these principles in practice. As further detailed below, sugarcane is a particularly suitable example, because sugarcane biomass is an important raw material for a wide range of bio-based products, including food (sugar and related products), bioenergy (ethanol, bioelectricity), bio-based bulk materials (bio-plastic) as well as bio-based high value products (e.g. flavors and fragrances). Sugarcane produces naturally simple compounds that are readily available for high-technology processing. This represents a considerable efficiency advantage compared to, for example, starchy products that need several treatments to produce simple structures (Nogueira and Leal, 2015). Moreover, sugarcane has a higher yield potential than other crops such as sugar beet or corn (Macedo et al., 2008). Sugarcane offers ample opportunities for the use of by-products that are derived from joint production with the main products and for the cascading use of biomass, which utilizes used products again. To ensure that the sugarcane sector complies with the principles of the circular economy (see above), both the cascading use of biomass and the utilization of by-products are required so that as many products as possible are derived from the biomass prior to its energetic use. As long as

biomass is not transformed into energy, it acts as a carbon sink. Thus, the use of by-products and the cascading use of biomass contribute to a lower environmental impact (Essel and Carus, 2014).

The world's leader in sugarcane production is Brazil, which makes it an interesting country for this case study. Moreover, Brazil has already played a pioneering role in promoting the use of bioethanol derived from sugarcane. This paper aims to analyze how well Brazil is positioned to meet the new opportunities and challenges of the bioeconomy, specifically ensuring a cascading use of sugarcane biomass and producing novel high-value bio-based products.

For the purpose of this analysis, this paper combines two conceptual tools: the concept of the 'biomass value web' and the concept of the 'national innovation system'. The concept of the biomass value web was specifically developed as an extension of the value chain concept to capture the complexity of the bioeconomy (Virchow et al., 2016). This concept takes into account that the cascading use of biomass leads to the interlinkage of different value chains, which can be analyzed as a 'value web'. The value chain concept was originally used by Porter (1990) to analyze the competitiveness of national industries in an international context. In a similar vein, the value web concept can be used to analyze the international competitiveness of a set of industries in a country that use the same type of biomass. As in the case of value chains, innovation is key to develop a well-functioning value web and to ensure international competitiveness for the various products and by-products derived from a type of biomass. To analyze the role of innovation, this paper combines the biomass value web concept with the concept of the NIS. This concept draws attention to the diverse set of actors involved in promoting innovation and to the linkages among them. The development of a well-functioning value web requires an expansion of the existing innovation system to involve new actors, such as research organizations and companies that focus on novel products from sugar cane (e.g. fragrances and flavors) and on technologies that make a cascading use of biomass possible. The NIS concept acknowledges that stimulating network formation and development among diverse actors is an important policy measure for reaching international competitiveness. Fostering such networks of actors is even more important in a value web than it is in a value chain. Still, network formation has often been neglected in existing innovation policies (Kaufmann and Schwartz, 2008).

To apply the concepts of the biomass value web and the NIS empirically, this paper combines conventional interview techniques with a relatively new method of data collection: the "Net-Map" tool (Schiffer, 2007). This tool focuses on the visualization of networks in the interview process, which makes it particularly suitable to collect data on biomass value webs and on the actors involved in the innovation system. By analyzing a case that has high potential to realize the principles of the bioeconomy formulated by the Global Bioeconomy Summit, 2015, and by combining different conceptual tools and data collection methods, this paper aims to make both a thematic and a methodological contribution to the analysis of the emerging bioeconomy. We expect that the findings from our case study are not only relevant for sugarcane and Brazil, but that they also provide insights that are relevant for other types of biomass and other countries.

The paper is structured as follows: Section 2 reviews the development of the sugarcane sector in Brazil from a historical perspective, as this provides important background information for the analysis of the current situation. Section 3 describes the conceptual tools and empirical data collection methods used for the case study. Section 4 presents the results, which are subsequently discussed in Section 5. Section 6 presents conclusions and policy implications.

4.2 History: development of the sugarcane sector in Brazil

In order to assess the potential of Brazil's sugarcane sector to realize the new opportunities of the bioeconomy, it is important to understand how and why this country has succeeded in becoming the world leader in sugarcane and bioethanol production. Brazil has favorable agro-climatic conditions for the production of sugarcane, but as pointed out by Porter (1990), natural conditions are usually not sufficient to gain international competitiveness. Investments in 'factor upgrading' and the development of demand conditions are important, additionally shocks are often crucial as well (Andrietta et al., 2007; Arruda, 2011; Furtado et al., 2011). Brazil's success can be traced back to the economic crisis of 1929, which stimulated the federal government to invest in the creation of a sugar buffer stock and to create the Sugar and Alcohol Institute. The use of ethanol blended with gasoline as automotive fuel was also introduced in the 1930s to increase the demand for sugar (Furtado et al., 2011). After World War II, the sector benefitted from an increasing domestic demand and advances in breeding and agronomic practices. A second major government effort to support the sector was caused by the oil price crisis of 1973, which led to the establishment of Proalcool, the National Alcohol Program in 1975. Government efforts were renewed as a consequence of the oil crisis of 1979. The sector remained heavily dependent on government subsidies, which took its toll when funds were allocated to other economic activities during the late 1980s. The effect was aggravated by the so called oil counter shock. Oil prices fell sharply, which affected the value of petroleum products as well as ethanol prices (Furtado et al., 2011, p. 159). This caused a dramatic fall in sales of cars fueled with 100% ethanol (Andrietta et al., 2007; Matsuoka et al., 2009).

In the early 1990s, Brazil opened its economy to external markets. During this process, state interventions such as production quotas of sugar and ethanol were removed and prices were determined on the free market. While the ethanol market was stagnant, the sugar market flourished, and Brazil became the major exporter of sugar worldwide in the early 2000's (Furtado and Scandiffio, 2006). The scenario changed for ethanol with the introduction of the flex fuel cars in 2003, which can run on a mixture of ethanol and gasoline or any of the two independently (Arruda, 2011; Furtado et al., 2011).

Currently, the sugarcane mills collaborate closely with distilleries which facilitates a flexible response to changing market demands. Moreover, after the deregulation of the market in the 1990s, mills invested in high-pressure boilers to generate electricity from bagasse surplus, which increased their efficiency. In view of the current low oil prices, the sugarcane sector faces similar challenges as in the past when oil prices dropped in the 1980s. These challenges were addressed by innovation, such as flex fuel cars and by a multiple use of biomass, including the generation of bio-electricity. Research on total factor productivity (TFP) also underlines Brazil's success in gaining competitive advantage through innovation. TFP change

measures the difference in growth between total output and total input. The share of output growth that is not caused by increased use of inputs can be attributed to productivity gains, which are due to innovations that increase the efficiency of production (Fuglie et al., 2007). Gasques et al. (2012) analyze TFP growth in agricultural production, which can be interpreted as an important indicator for innovation in biomass production. The authors show that the growth of Brazilian agriculture was largely based on productivity gains: between 1970 and 2006, input use increased by 53%, whereas agricultural output increased by a remarkable 243% (Gasques et al., 2012). For the period from 1995 to 2006, 32% of Brazil's agriculture growth was explained by an increase of inputs whereas 68% can be attributed to innovations.

As research on the Brazilian sugarcane innovation system has shown, different types of actors have contributed to the country's success. These include publicly-funded research organizations and universities that benefitted from the government's research programs as well as networking efforts, private companies that invested in innovations for industrial equipment used in mills and distilleries, and start-ups that pioneered biotechnology innovations (Furtado et al., 2011). These findings are in line with research on innovation networks, which have been found to greatly influence the innovative performance of firms and of entire regions (Buchmann and Pyka, 2014; Fleming et al., 2007; Schilling and Phelps, 2007). Research also shows, however, that the emerging bioeconomy may challenge existing innovation networks. For firms to remain competitive, they need to reposition themselves in a larger network and gain access to diversified knowledge (Coff, 2003; Dierickx and Cool, 1989). The following case study will explore to what extent the Brazilian sugarcane innovation system is moving in this direction.

4.3 Methodology

This section starts with an explanation of the concepts used for the analysis of the case study. In the second part of this section, the empirical research methods are presented.

4.3.1 Conceptual framework

As explained in the introduction, two conceptual tools are used in this case study: the concept of a value web and the concept of the NIS.

4.3.1.1. The Biomass-based value web

As indicated above, the concept of the value web is an extension of the value chain concept. This paper draws on the concept of a 'biomass-based value web', which was developed by Virchow et al. (2016) with the specific goal to provide a tool for analyzing the multiple uses of biomass in the bioeconomy. As pointed out by the authors, the concept uses the 'web perspective' as a multidimensional framework to understand the interrelation and linkages between several value chains and how they are governed […]. The web perspective helps explore synergies between value chains, identify inefficiencies and pinpoint potential for sustainable productivity increases in the entire biomass-based value web of a defined local, national or international system" (Virchow et al., 2014 p.18).

The value web aims to cover complex pathways of biomass and to integrate social, economic and environmental perspectives (Virchow et al., 2014). Due to an increase in complexity of

value chains and the inclusion of diverse activities, system boundaries are less definable and the cost of data collection as well as the availability of data might become challenging. The biomass web is especially suited for agrarian-dominated economies. In contrast, the concept of industrial ecology focuses on industrial processes and their impact on the environment and quantifies the material flows (Frosch and Gallopoulos, 1989). Such quantification is not done in this paper, but could be a further step of investigation.

The term 'value web' has been used in the business literature before, but it was used in a different sense (Allee, 2001; Andrews and Hahn, 1998; Cartwright and Richard, 2000; Gordijn and Tan, 2005; Pijpers and Gordijn, 2007). In this literature, the concept was applied to analyze the collaboration between enterprises, where corporate boundaries are fluid and increasingly flexible, and customers are increasingly included as value exchangers. The concept was applied to a range of industries including virtual enterprises such as finance, e-commerce, internet service provisioning, and news.

The use of the value web concept in this paper is compatible with the earlier uses of the concept in the business literature. However, the concept is used here in a more specific sense. The 'biomass-based value web' takes the physical flow of biomass as the basis of the analysis. The actors involved in the value web can then be identified based on their involvement in the production, processing, trade and use of the biomass and the products and byproducts that are derived from it. Since the concept does not only focus on physical resource flows but also serves to identify the actors involved, it can be combined with the concept of the NIS, as further explained in the following section.

An important reason to apply the concept of the biomass-based value web is the fact that it can account for joint production as well as for the cascading use of biomass highlighted in the introduction. The same type of biomass can be utilized in different value chains and it can also substitute carbon-sources from other conversion processes. For example, residues from sugarcane processing can replace fossil fuel sources. Therefore, the concept of the biomass-based value web can also be used to analyze the environmental benefits which can be attributed to the cascading use of biomass and by joint production schemes, such as reductions in GHG emissions.

4.3.1.2 The National Innovation System (NIS)

The concept of the 'National System of Innovation' was originally developed in the 1980s by researchers who aimed to understand the structure of and the actors involved in processes of innovation in some industrialized and emerging economies (Balzat and Hanusch, 2004). According to Lundvall (1992), a pioneer of NIS research, an NIS can be defined as the "elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge […] and are located within a nation state in a national-cultural and etatist-political sense" (Lundvall,1992, p. 3f). An essential contribution of the NIS literature is the insight that innovation does not only rely on investment in research and technology development. What matters are synergies within and between science, technology, economy, policy and culture along with complementarities between regions and the whole country (Freeman, 2002). As shown in the NIS literature, the types of relationships between actors play a crucial role for the performance of an NIS. Non-market oriented and stable

(longterm) relations improve information transfer as well as interactive learning, because actors can build on "power, trust and loyalty" (Lundvall et al., 2002, p. 218). The definition of the NIS emphasizes the importance of the learning capability of a nation, the organization of financial support and a business service that generates and trades knowledge (Lundvall et al., 2002).

Drawing on these insights, the NIS concept is applied in this paper to analyze business and knowledge interactions among the different actors involved in the biomass-based value web. As further detailed below, concepts of social network analysis are used for a quantitative assessment of the knowledge and business linkages that were identified in the value web. Following Pyka (2002), we use three measures of social network analysis: the centrality measures for degree, closeness and betweenness. These measures, which are further explained below, are applied to identify how well Brazil is prepared to develop a competitive bioeconomy innovation network. The measures capture important preconditions for Brazil's ability to make use of new opportunities and develop a competitive value web based on sugarcane biomass. This study does not aim to quantitatively assess the current innovation performance of the sugarcane value web in Brazil, it rather aims to provide a conceptual basis for such assessments.

4.4 Empirical research methods

The empirical investigation focused on the state of Sao Paulo, as it is the largest producer of sugarcane in Brazil. This section describes the empirical research approach that was applied for the case study.

4.4.1 Sampling and data collection

The first step in data collection was a visualization of the sugarcane value web. This was done with purposively selected respondents who were knowledgeable about the sugarcane biomass flows. In each interview session, an A2 sheet of paper was used on which the flows from the raw material 'sugarcane biomass' to the different products were drawn, based on the information provided by the respondents. The results were cross-checked with data from the literature. The visualization of the biomass value web included both traditional products that are already produced well as potential sugarcane biomass uses that may be used in the future. The value webs also show the current extent of cascading use of byproducts in the sugarcane sector and potentials that exist. The same map was also used to identify the different types of institutions involved in the physical flow of biomass and its products. By identifying the institutions involved, the maps give an overview of the innovation network from a bioeconomy perspective.

In the next step, respondents from the different types of institutions identified through the mapping exercise were purposely sampled. The aim was to identify respondents who closely collaborate with other institutions in the sector; this is particularly true of research institutions and universities. The researchers conducted semi-structured individual interviews with these respondents, focusing on challenges and opportunities of the sugarcane-based bioeconomy. These interviews also served to identify organizations that did not appear in the mapping of

the biomass value webs, but which were seen as relevant for innovation in the value web. Subsequently, respondents from these organizations were interviewed as well.

In the fourth step, the Net-Map tool from Schiffer (2007) was applied to capture the complete picture and empirically assess the linkages among the actors involved. The application of this tool is explained in more detail below.

The data collection approach was designed to match the conceptual framework outlined above. In particular, it allowed for (i) the extension of the value chain approach to include the utilization of by-products as well as the inclusion of cascading use of biomass and (ii) the inclusion of several heterogeneous actors that would otherwise be left out in a traditional sector analysis.

The approach outlined above resulted in 21 in-depth interviews of at least 1.5 h each. To ensure data quality, member checks were carried out verbally throughout the interviews by using paraphrases and summaries for clarification during and after the data collection dialogues (Shenton, 2004). Moreover, both the mapping of biomass value webs in the first step and the Net-Maps drawn in the fourth step rely on the visualization of networks during the interview process itself. This approach allows for constant crosschecking of interview information with the respondent, thus increasing the reliability of the information obtained. Additional member checks were conducted after the study was completed. Moreover, the participation of respondents from several different organizations reduced bias that may stem from the specifics of a particular institution. Triangulation with secondary literature was also conducted. The interview information was compared with policy documents, such as the National Plan on Climate Change (Decree No. 6263 of November 21, 2007), the Biotechnology Development Policy (Decree No. 6041 of February 8, 2007), annual reports of companies and publications from the Brazilian Agricultural Research Corporation (EMBRAPA), especially from the agroenergy unit, documents published by the Brazilian Sugarcane Industry Association (UNICA) and peer-reviewed literature. Furthermore, the findings were presented and discussed with peers at the annual conference of the International Consortium on Applied Bioeconomy Research (ICABR) in Ravello (Italy) and at the Tropentag Conference in Berlin in 2015. Finally, the combination of different research methods compensated for the limitations of individual methods (Brewer and Hunter, 1989; Guba, 1981).

4.4.2 The Net-Map Tool

Since the Net-Map tool played an important role in data collection, it is described here in more detail. The application of the tool involves the following steps:

1) The researchers explained to the interviewees the aims of the research. They pointed out that the underlying goal of the Net- Map session was to describe and understand the linkages between actors in the sugarcane sector in the production of traditional and new ‘bio-economic products’. A blank A2 size paper was used to draw the map.

2) The interviewees were asked to identify the actors involved in the development and production of different sugarcane products (from traditional to bioeconomic products), and to indicate what other actors would be important to strengthen the development of the Brazilian

bioeconomy. Colored sticky notes were used to depict the actors and to categorize them into different groups (e.g. private or public institutions, international actors, etc.). The notes were put on the A2 sheet.

3) In the next step, the interviewees were asked to identify knowledge flows and business linkages between the different actors. One- or double-sided arrows were drawn on the map sheet in different colors to distinguish these two types of linkages. A caption on the side of the map described the colors of notes and links that were set up.

4) After completing the drawing step, the interviewees were asked to review whether all institutions and actors in the sugarcane sector were included and whether there was a need to add linkages to the map. Additionally, the interviewees were asked whether they could identify any additional actors that are important for the development and production of 'bioeconomic products' who were not yet considered in the map. The respondents were also asked to rank the actors according to their importance for the bioeconomy.

5) An important final step of the process was the discussion of the Net-Map with the interviewee. The visualization of the innovation network made it possible to follow up with question on the role of different actors and on opportunities and bottlenecks in the system.

For documentation, the entire process was recorded with a voice recorder and the map was photographed.

To analyze the findings from the Net-Maps, the diverse actors identified in the different interviews were clustered into 16 groups according to their role. They are listed in the right column of Table 9. For further analysis, the actors were grouped into six clusters, which are shown on the left-hand side of Table 9.

The results from the individual Net-Maps were then combined into one final map, which only indicates these 16 categories of actors. The final maps, which are shown in Figs. 6 and 7, display the knowledge and business flows between actors. In these network diagrams, the actors are shown as the nodes of the network. The figures reflect the results from the Net-Map exercise, the interviews and literature information that were used for triangulation.

Table 9: Representation of clusters and groups of actors used in the analysis

Clusters used in the Adjacency matrix	Groups
Public Funding Agencies	Government Research Funding Agencies
Industry	Capital Goods Industry Energy Supplier National Chemical Industry Startups Fuel Distributors
Sugarcane Sector	Mills Ethanol Producers Sugarcane Farmers Cooperatives and Associations
Public Research	Research Institutions Universities
National crop breeding Institutions	National Crop Breeder
International Biotechnology Industry	International Breeder International Chemical Industry

4.4.3 Data analysis

The interviews were analyzed inductively using content analysis to identify unique and recurring themes (Glaser and Strauss, 1967). During the Net-Map exercise and the interviews, knowledge flows and business linkages were assessed. The connections are represented by arrows and the spires indicate the direction of the linkages. When an exchange of knowledge occurs, the arrows are double spired to display knowledge flows in two directions. The networks derived from the Net-Map method and supporting information were then analyzed quantitatively using the methods of social network analysis, as further detailed below.

Analysis of knowledge and business flows using UCINET: The UCINET software (Borgatti et al., 2002) developed for social network analysis is applied to derive statistical measurements of degree, closeness and betweenness centrality among actors. The two linkages were identified from the Net-Map sessions: knowledge flows (formal and informal, including personnel) and business linkages. Knowledge flows are considered links that enable the creation and transfer of knowledge, and as being the driving force of economic growth, social development, innovation and the basis for competitive advantage. Business linkages are, in this case, links that facilitate the transfer of technology, contribute to business and management practices, to production efficiency, productivity growth, technological capabilities and market diversification that involve an exchange for other goods, services, or money. In the case of degree and closeness centrality the direction of linkages are displayed as InDegree and OutDegree, indicating incoming and outgoing links of a node.

(1) Degree centrality: Degree centrality shows the number of connections an actor has in relation to others. Higher visibility of an actor is determined by a large number of interactions, thus deemed more powerful in the given network. In the case of knowledge for instance, a very well connected actor has more knowledge sources than others and could acquire new knowledge more easily.

(ii) Closeness centrality: Closeness centrality calculated by the UCINET software refers to Freeman (1978). Closeness centrality measures the average number of steps needed to reach other actors. It is measured by dividing the total amount of edges/nodes, minus one, by the sum of all geodesic distances from one node to all other nodes. As closeness measures only make sense when nodes are linked, unconnected nodes were omitted from the calculation. The higher the closeness value, the more the respective agent is interlinked in the network with easier access to the sources of the flow.

(iii) Betweenness centrality: The concept refers to geodesic distances between three actors. It focusses on an actor's role as an intermediary. Betweenness expresses the number of shortest paths that go through one node; a higher value indicates a higher frequency of the actor playing an intermediate role between two others (Borgatti, 2005). If actors have a high betweenness level, they are expected to have greater power in the network since they are able to control the flows passing through them from one actor to another.

(iv) Adjacency matrix: The 16 stakeholder groups were further condensed to six clusters: industry, national and international crop breeding institutions, international biotechnology firms, research institutions and universities (Table 14). This simplification permitted the UCINET software to run an adjacency matrix which calculates the percentage of the links that actually were realized out of all possible links between the clusters.

4.5 Results

This section starts with a representation of biomass flows in the sugarcane value web. In the following, the results from the interviews are presented. The third subsection displays the results from the quantitative analysis of the value webs.

4.5.1 Results from the mapping of biomass flows

The sugarcane biomass flows, illustrated in Figure 5, identify the current physical fluxes of feedstock and the potential uses that are envisaged by research and industry.

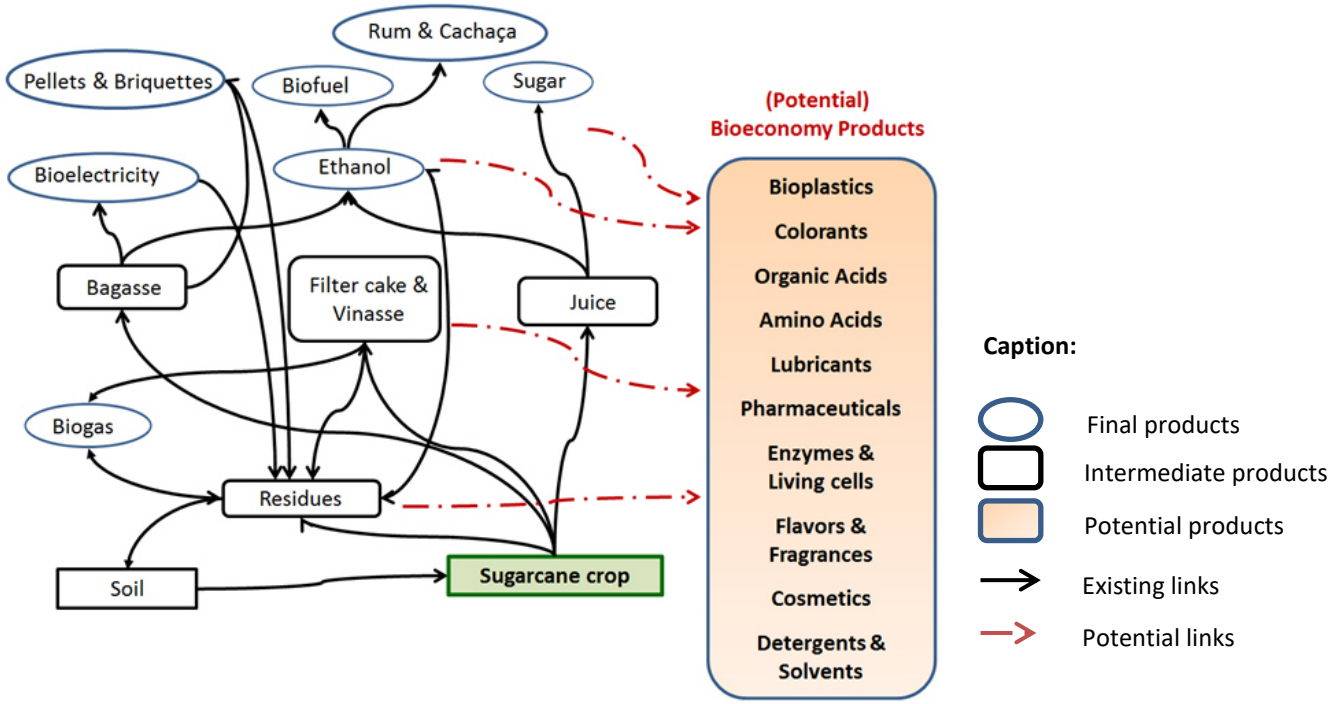

Figure 5: Biomass flows in the sugarcane value web

The sugarcane biomass flows, illustrated in Fig. 5, identify the current physical fluxes of feedstock and the potential uses that are envisaged by research and industry. The sugarcane products represented in Fig. 5 were used to identify the institutions that constitute Brazil's sugarcane innovation system. The stakeholders involved in the development, transformation, utilization and commercialization of the biomass are depicted in Table 10. The identified stakeholders are not only relevant for the development of bioeconomic uses of sugarcane biomass but are also involved in the NIS.

Table 10: Biomass products of the value web used to identify the corresponding institutions

Institution \ Biomass products	Agricultural inputs	Sugarcane stalks	Straw (tops & leaves)	Filter cake	Bagasse	Vinasse	Cane juice	Biogas	Ethanol	Sugar	Bioelectricity	Potential bioeconomy products
Capital good industry	X				X			X	X	X	X	X
Energy supplier									X	X	X	
National chemical industry	X	X	X		X		X			X		X
Startups		X	X		X			X		X		X
Fuel distributors										X		X
Government		X							X	X	X	X
Research funding agencies	X	X	X	X	X	X	X			X	X	X
International breeder companies	X	X	X							X	X	X
Mills	X	X	X	X	X	X			X	X	X	
Ethanol producers		X	X		X					X		
Sugarcane farmers	X	X										
Cooperative/Associations	X	X	X						X	X	X	X
National crop breeders	X	X	X						X	X	X	X
Research institutions	X	X	X	X	X	X	X	X	X	X	X	X
Knowledge institutions	X	X	X	X	X	X	X	X	X	X	X	X

4.5.2 Interview Results

The main results from the interviews on the opportunities and challenges of the sugarcane sector are summarized and presented, with the corresponding number of interviewees mentioning them, in Table 11.

Three main opportunities were highlighted during the interviews: 1) advantages from the long sugarcane growing tradition, 2) governmental support and 3) the potential to both increase resource efficiency as well as expand the overall product portfolio. The long growing tradition is particularly relevant for the acquired agronomic knowledge and long-term research on sugarcane varieties that was carried out. The role of sugarcane and ethanol producers' organizations, such as cooperatives and associations, were highlighted as supporting knowledge transfer. Political will has enabled well-functioning research collaborations with formal and informal knowledge exchange. The potential for the development of new products was acknowledged. Criticisms of missing interactions between Brazilian and international companies that engage in the biotechnology sector were raised. Interviewees agreed that there is a lack of qualified individuals, entrepreneurship and technologies but claimed that there is sufficient support for bioeconomy-related research. Both interview partners from public and

private sectors claimed that there is still significant potential for improvements with regard to public-private collaborations. The main impediment to greater interactions between public research and the industry is the bureaucratic process that unfolds, for example, in the registration of patents. It ultimately renders such collaborations undesirable. Currently, the sugarcane sector is facing various challenges. Due to low fossil fuel prices and the financial crisis, multiple sugarcane mills had to close. Since most of the mills were bought by bigger companies, the overall sugarcane yields did not decrease. However the current stagnation in the sector will likely further contribute to supply shortages in the future. Due to these financial difficulties, most of the mills have to focus on cost reduction and are currently unable to allocate resources for further investments. Even though government support was identified as a driver and opportunity for the industry, political actions also challenge the sector. Funding opportunities are highly restricted and specific, which makes it difficult for private and public actors to apply for them. Additionally, high tax burdens for companies and regulations that support the fossil fuel sector create deterrents, especially for small-scale producers. The private sector particularly suffers from competition between the free market of sugarcane and the government-regulated fossil fuel market. Another big concern for bioeconomic development is the legislative uncertainty, especially for academics and entrepreneurs.

In addition to institutional challenges, biomass is also affected by climatic conditions and shocks that are not amortized by specific support to the sector. Therefore, a strong concern was the series of droughts that Brazil has faced in the past few years, which lowered yields and increased costs of sugarcane. Nevertheless, all interviewees agreed on the nearly perfect climatic conditions for sugarcane in Brazil and the huge potential of sugarcane as feedstock for the burgeoning bioeconomy.

Table 11: Matrix of themes from key informant interviews

			7	9	11	13	14	16
Opportunities themes	**Factor conditions**	Good climatic conditions					X	
		Land availability			X			
		Very good energy balance of sugarcane biomass					X	
		Cost efficient biomass production					X	
	Firm strategy, structure and rivalry	Diversification of production portfolio, three main products: sugar, ethanol and energy						X
		Long history in sugarcane growing					X	
	Related and supporting industries	Very good research institutions					X	
		Advanced Breeding			X			
	Government policies	Share of ethanol blended into gasoline (currently up to 27%)			X			
		Government incentives towards biotechnology				X		
	Demand Conditions	Growing demand for biofuels			X			
	Socio-economic aspects	Positive spinoffs of social aspects from the sugarcane industry			X			
		No threat for food security		X				
Challenges themes	**Factor conditions**	Preserve protected areas (e.g. Amazonas, Pantanal etc..)	X					
		Climate change (e.g. droughts)			X			
		Preserve biodiversity			X			
	Firm strategy, structure and rivalry	Missing entrepreneurship					X	
		Mistrust between industry and academics						X
		Competition more important than knowledge transfer (in the 70's it was the another way around)				X		
	Related and supporting industries	Missing link between farmers sugarcane/ growers and the academics/researchers					X	
		Missing high educated personnel (especially qualified labour with tertiary education and higher for the development of the biotechnology sector)					X	
	Government policies	Fiscal policy supports the national economy in total but, the political instruments are partly harming the biofuel sector					X	
		Inconsistency of sugarcane sector related policies						X
		Financial crisis and political unrest						X
		Legislation hurdles for startups				X		
		Missing legislation for IP					X	
		Bureaucratic hurdles register patents and protect intellectual property						X
	Socio-economic aspects	Differences between the South and the North				X		

4.5.3 Architecture of the Innovation Web in the Sugarcane Sector

Figs. 6 and 7 display the innovation webs in the sugarcane sector. The results illustrate that business collaborations are always double-sided, with one exception: the connection between fuel distributors and the energy supplier is one-sided since fuel distributors have the alternative to sell the energy surplus to the national grid. Government and research funding agencies are excluded, as they do not participate in market interactions. Therefore, only 14 agents are considered.

Table 12: Centrality measures of the business linkages

	(Out)Degree Centrality	(In)Degree Centrality	(Out)Closeness Centrality	(In)Closeness Centrality	Betweenness Centrality
Capital Goods Industry	6	6	0.59	0.57	13.43
Cooperatives/ Associations	3	3	0.54	0.52	3.47
Energy Supplier	0	1	0.25	0.39	0
Ethanol Producers	9	9	0.77	0.68	62.07
Fuel Distributors	5	4	0.62	0.54	12.33
Government	0	0	-	-	0
Int. Crop Breeders	3	3	0.46	0.45	1.67
Int. Chemical Industry	7	7	0.68	0.62	11.80
Mills	6	6	0.65	0.59	12.40
Nat. Crop Breeders	6	6	0.65	0.59	12.40
Nat. Chemical Industry	2	2	0.48	0.46	0
Research Funding Agencies	0	0	-	-	0
Research Institutions	3	3	0.52	0.50	3.30
Start-ups	4	4	0.52	0.50	0.33
Sugarcane Farmers	2	2	0.50	0.48	0.80
Universities	1	1	0.45	0.43	0

4.5.3.1 Degree centrality of business linkages

Almost all flows are bilateral (InDegree equals OutDegree), except in the case of fuel distributors and the energy supplier. Ethanol producers have the best interlinked market actions and share nine productive links out of thirteen (Table 12). In terms of power ranking, after ethanol producers, the international chemical industry is most powerful, followed by national crop breeders, capital goods industry and the mills. Universities, the national chemical industry, and sugarcane farmers seem to be barely connected in market collaborations.

4.5.3.2 Closeness centrality of business linkages

The highest closeness centrality was reached by ethanol producers, followed by the international chemical industry. Mills and national crop breeders have the third highest value. The results are similar to that of the degree centrality measure. The capital goods industry does not have as high closeness centrality measures as mills and national crop breeders (Table 12). In terms of closeness, fuel distributors are better connected compared to the capital goods industry; although their degree value is lower than that of the capital goods industry. Universities, sugarcane farmers, and the national chemical industry continue to occupy the lowest ranks in closeness centrality. Furthermore, international crop breeders have longer distances to cover to engage other players in the network.

4.5.3.3 Betweenness centrality of business linkages

The results indicate high values for ethanol producers, the capital goods industry, national crop breeders and mills; they possess a privileged position since they are in control of the flow and can determine the speed of information passage within the network (Borgatti, 2005). Once again, universities and the national chemical industry are poorly involved in business collaborations (Table 12). Thus, betweenness centrality supports the results of the other centrality measures.

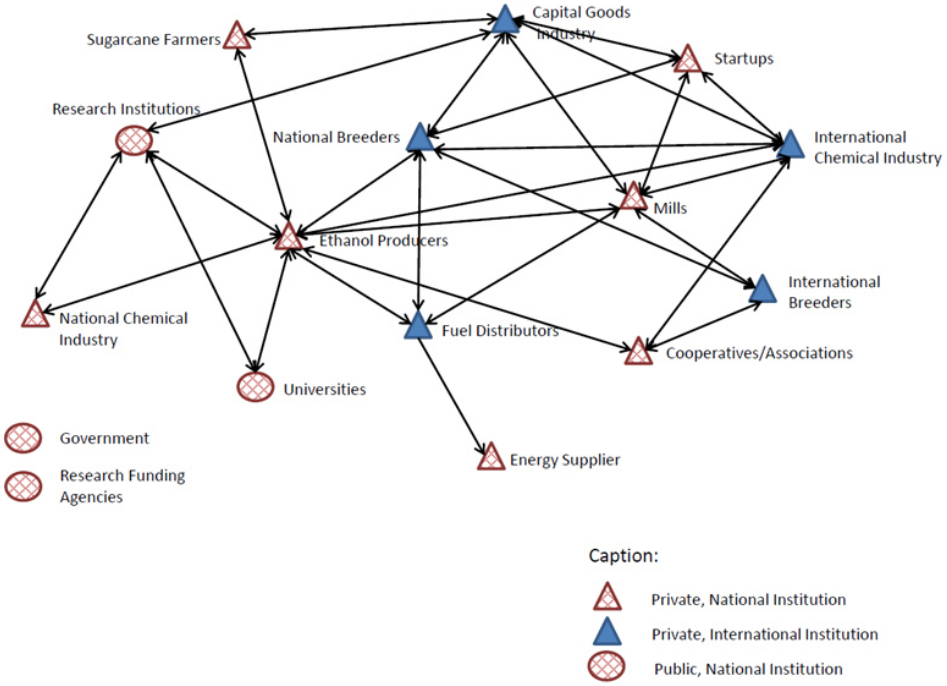

Figure 7: Visual representations of knowledge flows.

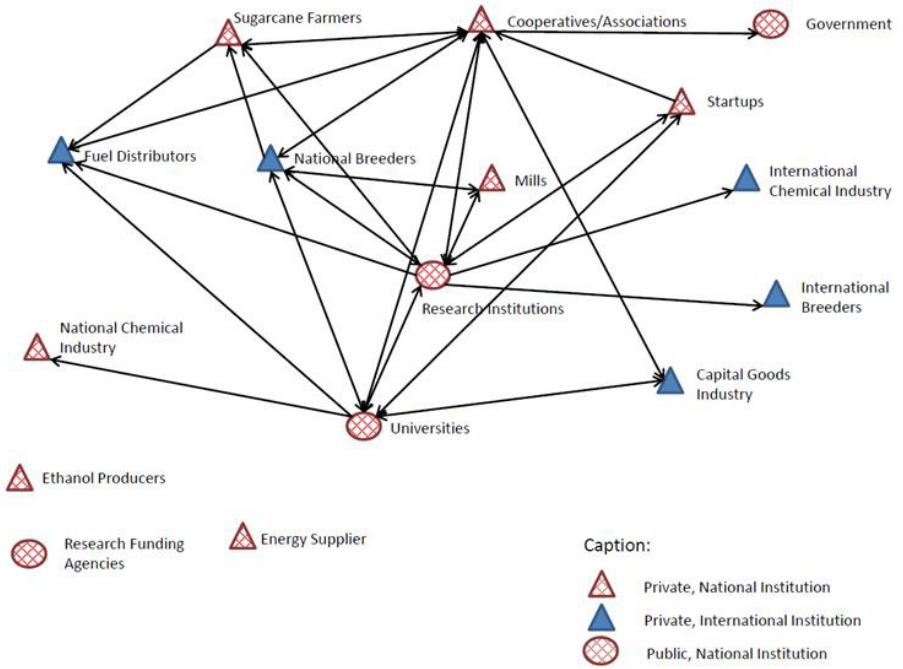

Figure 6: Visual representations of business flows

4.5.3.4 *Centrality, closeness & betweenness of knowledge flows*

Knowledge flows are important in biomass webs as they are crucial to promote innovation and foster comparative advantage in the bioeconomy. The findings from the Net-Map activity show that research institutions as well as universities are highly connected in the knowledge network, while ethanol producers are isolated (Table 13). Cooperatives and national crop breeders are well-linked, whereas research institutions and universities are 'sending' more information out than they receive. Cooperatives as well as fuel distributors get more knowledge links in. The betweenness centrality highlights the impact of cooperatives, research institutions and universities for knowledge transfer within the examined sector. In the closeness centrality analysis, national crop breeders and startups have short paths to new knowledge sources in addition to research institutions, universities and cooperatives.

Table 13: Centrality measures of knowledge flows

	(Out)Degree Centrality	(In)Degree Centrality	(Out)Closeness Centrality	(In)Closeness Centrality	Betweenness Centrality
Capital Goods Industry	1	2	0.38	0.37	0
Cooperatives/ Associations	5	6	0.57	0.43	42.17
Energy Supplier	0	0	-	-	0
Ethanol Producers	0	0	0.25	0.25	0
Fuel Distributors	1	3	0.39	0.38	0.40
Government	0	1	0.25	0.37	0
Int. Crop Breeders	0	1	0.25	0.36	0
Int. Chemical Industry	0	1	0.25	0.36	0
Mills	2	2	0.45	0.35	0
Nat. Crop Breeders	5	3	0.57	0.36	5.40
Nat. Chemical Industry	0	1	0.25	0.35	0
Research Funding Agencies	0	0	-	-	0
Research Institutions	8	5	0.62	0.42	40.67
Start-ups	3	2	0.52	0.35	0.40
Sugarcane Farmers	2	3	0.41	0.39	1.40
Universities	7	4	0.62	0.41	17.57

4.5.3.5 Adjacency matrix

To summarize the centrality measures we used the adjacency matrix introduced by Hanneman and Riddle (2005 p. 55): it "represents who is next to or adjacent to whom in the 'social space' mapped by the relations that we have measured". For the matrix, the sixteen groups are consolidated into six: industry, sugarcane sector, public research, international crop breeders and chemistry, public funding and national crop breeders (Table 14). The connections were further summarized in a binary matrix. An adjacency matrix calculates the percentage of actual existing interactions out of all possible linkages. In the case of 25 possible links, within the industry group, for example, only three exist so the result is 12% of fulfilled linkages. Industry and public research are interlinked at 80%, which is surprising and will be discussed in the next section. What is less surprising is the strong connection between public research institutions.

Table 14: Adjacency matrix of clusters, values in percentage

	Public Funding Agencies	**Industry**	**Sugarcane Processing Sector**	**Public Research**	**National Breeding Institutions**	**International Biotechnology Industry**
Public Funding Agencies	25	40	38	75	50	50
Industry	0	12	50	80	60	30
Sugarcane Processing Sector	13	40	56	63	100	63
Public Research	0	80	63	75	100	50
National Breeding Institutions	0	60	100	100	100	100
International Biotechnology Industry	0	30	63	50	100	0

Source: own calculations based on Hanneman & Riddle (2005)

4.6 Discussion

The aim of this study was to identify the potential of sugarcane as a crop for bioeconomic application and relate the biomass products to the institutions involved in its processing. Furthermore, knowledge transfer and business collaboration underlines the strength of an innovation system and therewith the development of the bioeconomy. The application of the biomass value web approach was used to identify novel biomass application pathways. It led to the identification of relevant actors from a wide range of professions and sectors that contribute to the NIS and are conducive for the development of the bioeconomy in Brazil.

4.6.1 Government and public funding agencies

The production of bioethanol is the principal application of the bioeconomy in Brazil. Nevertheless, the potential of biomass calls for interlinked collaborations (business linkages) and capacity building (knowledge flows) to foster the development of bioeconomic activities.

Kemeny (2011) found that Brazilian research builds on the country's own sources, suggesting a supportive internal environment for research. This worked very well in the past and resulted in internationally competitive sugar and ethanol production. However, it might not be sufficient to build a strong bioeconomic strategy in a context where biotechnology and the private sector gain importance. In the 1930's, investment in research and development (R&D) led, for example, to the development of the flex fuel cars which was the central innovation that made the ethanol market sustainable (Hira and de Oliveira, 2009). Currently though, the prices of fossil fuels are kept artificially low (de Moraes and Zilberman, 2014), which does not encourage the emergence of bio-based alternatives. State policies and regulations are not contributing to the emergence of a "vigorous domestic rivalry" which according to Porter (1990) is one of the preconditions to develop strong competitive advantage nationally and internationally. Instead, such policies undermine the stimuli for energy-saving technologies. Moreover, the government can stimulate the demand and development of bioeconomic products by acting as a 'sophisticated buyer'. This is of particular relevance for international demand (Porter, 1990) which is expected to shift towards bioeconomic strategies. From the results of the interviews and the Net-Maps, the role of the government is not yet predominant in shaping and raising the national bioeconomy in various sectors and disciplines. Recent studies claim that Brazil lacks innovativeness in most industrial activities, not only in sugarcane (Cassiolato et al., 2014). Rapid changes in government policies that affect the sector hamper long-term commitments by relevant stakeholders. In particular, the private sector criticized the lack of recognition for their efforts towards sustainable production practices.

4.6.2 The industry

The adjacency matrix illustrates that intra-industry links are rare. For an innovation network, these types of linkages are crucial, since otherwise knowledge generation is slow and expensive (Buchmann and Pyka, 2014; Pyka and Saviotti, 2002). From an industrial ecology perspective, networking and innovation are also crucial to efficiently use energy and strategically target material flows to conserve natural resources (Taddeo et al., 2017). Furthermore, little engagement of international biotechnology firms in business collaboration

with domestic firms is reported; the same applies to knowledge transfer (Tables 12 and 13). This implies that the current system is poorly positioned to cultivate innovation in the future bioeconomy.

The adjacency matrix shows that Brazilian multinational corporations are highly involved with international companies in joint ventures or other projects. This highlights interest from non-Brazilian companies in the locally available biomass. The biotechnology-intensive sectors in Brazil seem to have difficulties competing globally. The private sector is increasingly interested in the potential of this new market, even though most of the current processes are not yet economically viable. Firms, in general, noted the lack of highly qualified personnel and the lack of an overall stimulating investment climate in the sugarcane sector, especially in light of incoherent policies. Bodas Freitas et al. (2012) confirm that university-industry relations are mediated by students and employees with optimal outcomes for both partners when firms invest in networking.

Startups enjoy a privileged position, since many are funded by former university staff members. The upcoming companies are of crucial relevance for the development of new products and processes and should therefore be supported with policy and tax incentives.

Private sector interviewees claim that Brazil lacks entrepreneurial thinking. For an innovation system, commercialization of research and entrepreneurial thinking are equally important (Freeman, 1978; Lundvall et al., 2002).

4.6.3 The sugarcane sector

After the introduction of the flex fuel cars, co-generation of electricity was the innovation that affected the sector the most. The by-product bagasse gained new economic value and contributed to reduce the production costs of mills, and had a positive effect on the share of renewable sources in the overall energy matrix of the country. Nevertheless, mills do not receive any recognition for the environmentally friendly energy they deliver to the country's power grid. Another aspect to consider is reducing energy consumption through improvement in the technological efficiency of production processes, which is important to meet ecological targets, especially resource conservation (see, e.g. Cappelletti et al., 2014). In the growing bioeconomy, it will be important to reward these kinds of ecological initiatives and benefits.

Cooperatives and associations report the highest betweenness centrality scores in knowledge flows, highlighting their prominent role in the innovation network. They have been found to absorb information faster, but also to control the speed of its flow. Buchmann and Pyka (2014) confirm cooperatives and associations have a critical function as knowledge transmitters through the network. Cooperatives play a crucial role since farmers and smaller mills are quite isolated in the sugarcane network; they have limited financial capacity to acquire new technologies and are dependent on external financial support to improve their processes.

4.6.4 Public research institutions

In the map representing the knowledge flow (Fig. 7), the highest scores are held by universities, research centers, and breeding institutions. This underlines not only a favored

position to acquire and exchange knowledge, but also the strategic position of these institutions to reach the source of knowledge along the shortest path. Nevertheless, according to the interviewees, they do not contribute sufficiently to technological competencies of the private sector. Criticisms in the literature confirm that even though programs that foster academic-industrial links are available, there is a lack of academic contribution to technological capabilities of the industry (Berti, 2014; Ponomariov and Toivanen, 2014; Rodriguez et al., 2008). This provides further evidence of a dysfunctional innovation system (Etzkowitz et al., 2005; Viotti, 2002).

Several respondents reported that the main barriers in knowledge exchange and collaboration are the obsolete bureaucratic system and the absence of clear-cut legislation for intellectual property management. For the private sector this represents one of the major constraints for collaboration with public institutions. Along these lines, interviewees from public knowledge institutions revealed that the relationship between the researcher and the industry is undermined by the lack of mutual trust since there is little protection for the weaker partner. Douglas North, a founder of institutional economics, argues that "the profitability of investing in new knowledge and developing new techniques requires some degree of property rights over ideas and innovation. In their absence the new technology may not be forthcoming." (North, 1981, p. 8) In developed economies the largest fraction of patents is granted to firms and there is a strong association between the number of patents and industries' investment in research as well as of the number of scientists and engineers employed by a company. Those correlations are weak in Brazil (Cota et al., 2016). This calls for a simplification of the bureaucratic system and support for R&D networks (Bodas Freitas et al., 2012). Moreover, the rapid dissemination of research results to facilitate technology transfer is vital to strengthen the competiveness and innovativeness of the sugarcane sector, and advance the Brazilian bioeconomy. As Lundvall and colleagues stated (2002, p. 220), "the institutions that constitute trust are crucial for interactive learning and innovation capabilities" and "well defined and implemented property rights of different kinds" are essential in an innovative environment.

The linkages in the adjacency matrix show how from the total number of possible linkages between industry and public research institutions, 80% are actually maintained, whereas only 12% of the possible intra-industry connections are realized. The relatively frequent interactions between industry and public research were not expected. A closer look reveals that the interactions were of a different nature. The links from industry to knowledge institutions are mostly profit oriented whereas the same link in the opposite direction (knowledge institutions to industry) is weaker and implies negligible information exchange.

4.6.5 The role of national crop breeders institutions

Remarkably, national crop breeders are very active in knowledge flows and are well-linked to the industry (Fig. 7). Most national crop breeding institutions were privatized during the deregulation process. However, since they could maintain their former connections with research institutions, they enjoyed proximity to knowledge and additional profit from business interlinkages with the industry (Table 12). Mistrust was not mentioned as a concern in this case. Even though governmental support decreased, crop breeding institutions

succeeded in financing themselves through free market collaborations. Moreover, Brazil's success in sugarcane breeding attracted international companies. Recently, for example, two leading centers (CanaVialis and Allelix) were bought by Monsanto in 2008 (Arruda, 2011; Furtado et al., 2011). Such acquisitions could deplete the overall innovation capability of the national system in the long run.

4.6.6 The international biotechnology industry

The development of the sugarcane business cluster in the state of Sao Paulo was vital to achieving competitive advantage in sugar and ethanol production. To increase bioeconomical products and the exploitation of the biomass value web, the creation of a similar cluster could foster the bioeconomy in the country.

The high scores of the international chemical industry as well as the role of ethanol producers, capital goods industry, mills and national crop breeder institution are fundamental when examining the business linkage scores for the three centrality measures. This can be explained by the economic returns that underlie business relations and involve common projects in the biomass value web. Bio-technological products (e.g. yeast, enzymes) are supplied by international companies because technology is advanced and production processes are more efficient outside of Brazil. Interviewees from the private international institutions argued that government incentives should not be the main driver for innovation, but economic feasibility. The analysis of knowledge flows in the biomass web yields interesting results. A high knowledge transfer is one driver of the bioeconomy. The findings show that actors in the private sector (national and international chemical industry), who are expected to play a crucial role in the development of technology intensive products, report very low scores in both degree centrality and closeness centrality. This reveals their weak roles as knowledge exchanging agents in the network and is highlighted by the betweenness centrality value of zero. For the development of the bioeconomy, their expertise is vital and non-market interactions are more valuable for information transfer and innovation development than pure market relationships (Lundvall et al., 2002). Crossover points and contributions from different disciplines and from public and private funded research hold great potential to generate spillover effects and create bioeconomic relevant processes and products. Nevertheless, links between national and international industries carry opportunities and risks. Globalization can potentially increase the knowledge gap between developed and developing countries, particularly in the case of knowledge and research intensive processes (Kemeny, 2011).

The bioeconomy would profit from the development of a new paradigm of innovation systems since a broad spectrum of topics need to be enclosed and the conventional structures of autonomous disciplines need to be reshaped. It is crucial to achieve a comparative advantage in the bioeconomy that intensifies transfers between business, civil society, politics and academia in all the various segments of the value web.

4.7 Conclusion and implications

The aim of this study was to identify the strengths and shortcomings in Brazil's innovation system with regard to the potential of sugarcane biomass in the imminent bioeconomy. The framework outlined in this research used the biomass value web concept to identify the actors that are embedded in the sugarcane innovation system. This method captures the larger spectrum of sugarcane biomass uses including potential applications. This is particularly interesting for the study of sugarcane in Brazil, where strong government policies have been instrumental in developing the sector, and agronomic achievements have produced a price competitive biomass e one pillar of the bioeconomy. The results illustrate the viability of sugarcane as an alternative to fossil fuels and the willingness to shape markets and technologies towards a bio-based system. However, new challenges have to be addressed when competing for new knowledge-intensive high technology products and processes.

The results suggest that Brazil has to overcome hurdles and create incentives to foster the innovation system. First, the current bureaucratic system needs to be simplified to achieve a higher degree of collaborations to support the development of new technologies and exploit the synergies of different disciplines. A transparent and simplified legal system is expected to increase the protection of partners and foster trust. The same is true for registration of patents. A straightforward and transparent share of the duties and achievements would be beneficial for collaboration between private sector and research institutions. Second, strengthening the exchange of qualified employees between research and industry would be beneficial for both types of institutions. Thirdly, great potential lies in the development of public-private partnerships that could be further supported by policies stimulating co-funding opportunities and long term projects to encourage investment in pre-competitive economic research. Long term investment schemes are relevant to attract collaboration across research fields that still bear many challenges and are far from becoming competitive in the near future. Therefore, individual stakeholders are not incentivized to tackle such issues on their own. As much as research and investment in efficiency and high value bioeconomic products (e.g. materials, chemicals and energy) using biotechnology based processes are needed, further development of co-funding strategies between government and private sector funds would support investment intensive projects.

Finally, a number of potential shortcomings need to be considered, given the dynamic evolution of the sector and the complexity of a multidisciplinary and multi-stakeholder study. The analysis was limited by the focus on only one crop in the agricultural sector. Synergies between value chains of different crops have not been considered. The broad understanding of the factors included in the bioeconomy makes it challenging to define the system boundaries; therefore it is possible that some aspects that might be critical for other bioeconomy settings might not have been considered. Therefore, caution must be exercised when transferring these results to other sectors.

Despite these limitations we believe our work applied a suitable framework on how to assess the institutional collaboration, based on physical biomass flows needed to foster the national bioeconomy.

To conclude, making better use of synergies between the well-established sugarcane sector and the national and international organizations with competence in biotechnological applications will be essential for the further development of the Brazilian bioeconomy.

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Chapter 5

Discussion

This thesis is relevant to contemporary research on the rising topic of the bioeconomy and the contribution of networks, institutions and governance challenges to the successful implementation of programs that play key roles in the development of the bioeconomy strategies. To interpret the results of the three papers, this chapter will refer to the story of the eagle believed to be a chicken (Chapter 1, Box 1 p.4). In the fable, the majestic bird can finally unfold its potential and assert his role as king of the sky, instead of behaving as a chicken, through the joint effort and vision of different actors who combine their knowledge and efforts.

The insights of this thesis can inform both, researchers and decision makers, on the shortcomings that need to be addressed to develop a sustainable bioeconomy. The interdisciplinary approach of this thesis helped exploiting synergies of various methods to identify challenges along complex research topics. Gaining insights on beliefs and root causes of challenges is fundamental for the implementation of development strategies, and it can harness the potential of natural resources.

5.1 The eagle and the bioeconomy: Link to the conceptual framework

Increased biomass production is an underlying condition for the development of the bioeconomy. Therefore, the second chapter of this thesis takes a comprehensive approach, combining socio-economic and lab based data, to determine which factors are preventing the fertilizer subsidy program from increasing yields and food security in the Guinea savanna of Ghana. As in the story of the eagle, only through the collaboration of actors with different knowledge and backgrounds, the eagle unlocks its potential and finally flies. The third chapter makes use of an in-depth qualitative approach, and analyzes the role of female-led market institutions, which are believed to act as cartels. However, when fully understood, these associations have the potential to support the development of far-reaching and socially acceptable policy designs. Narratives, as in the case of the fable in which the farmer considers the eagle to be a chicken, need to be understood, for they can be powerful. The fourth chapter combines the biomass value-web and the national innovation system approach to identify entry points in the Brazilian innovation network, which could foster the development potential of new products and processes in the sugarcane sector, and take advantage of previous achievements in the application of the bioeconomy. The importance of commitment towards a shared goal and of collaborations between actors is reflected in the story. Through the joint effort of community members and the scientist, the path towards the mountaintop is successfully undertaken and the eagle finally unfolds its potential.

5.2 Summary of main results

This section summarizes the empirical findings of the three studies and places them in the context of existing literature. For simplification in the coming sections Chapter 2 will be

referred to as the “fertilizer study”, Chapter 3 is referred to as the “market queen study”, and the final paper is referred to as the “Brazil study”.

The fertilizer study analyzes the challenges faced by popular government policy, which is held to be decisive policy intervention to address the persisting yield gaps in Ghana. Despite a considerable share of public spending allocated to the fertilizer subsidy programs, overwhelming evidence has revealed the inefficiency of the policy measure. This study employs a multidisciplinary approach to identify the determinants of low maize yields in the Guinea savanna of Ghana. Socio-economic household survey data was combined with data derived from soil laboratory analyses. A production function and a Tobit model were computed based on both socio-economic and soil specific variables. The models revealed that a widely spread parasitic weed, striga spp., and labile soil structure have profound effects on maize yield variability. However, the results confirmed governance challenges in the distribution, these included targeting, timing, and elite capture problems. The study finds the fertilizer subsidy program to be an ineffective standalone measure. Additionally, fertilizer samples from randomly selected agro-input shops were analyzed to control for adulterated or fake inputs. Laboratory testing was used to analyze the soil and fertilizer samples. The measured nutrient contents of the fertilizer samples reflected the composition indicated on the package labels.

The market queen study seeks to identify the role of female-led trader associations across markets in Ghana. In Ghana, markets are largely managed by women traders that form groups based on the main commodity being trade. In the public narrative and limited literature, market queens have a negative connotation and are perceived as “cartel” and “mafia”-like institutions. This study aims at investigating: 1) the nuances of these female-led institutions 2) the structure and function of the associations, and 3) the perception of the association from members outside the market. The study employs a purely qualitative research approach. Participatory observation and open-ended in-depth interviews were applied to assess the role of the association leader and the institution in the market. The study covers all ten regions of Ghana and reaches across different market typologies. Expert interviews with public and private sector stakeholders complemented the data. The findings illustrate that the market associations are democratic, hierarchical, collective action institutions offering savings, insurance and credit services to traders. The structure varies between ethnic groups and commodities, however in all instances they are a crucial link to ensure all aspects of food security for the urban and rural populations. Contrary to current literature, the results do show evidence of the associations leveraging their power to set market prices. The empirical findings challenge the negative representation of female traders associations and highlight the need to recognize them as valuable actors crucial in the value chain.

The fourth chapter aims to explore the innovation system directed towards bioeconomy in a rather advanced context. The case of the sugarcane sector in Brazil is an exemplary case on how political commitment has supported the shift from gasoline to ethanol as a terrestrial fuel source. However, the bioeconomy envisions the use of biomass to replace material and processes currently based on crude oil with biomass-based materials. This chapter therefore seeks to identify the opportunities and challenges faced by the innovation system of the

sugarcane sector in Brazil when attempting to develop a new set of products and processes in hopes of more efficiently using biomass resources. The study combines two conceptual tools: one is the 'biomass-based value web', which was developed as an extension of the value chain concept with the aim to capture the linkages within and between value chains that arise from the cascading use of biomass. The second concept is the 'National Innovation System' (NIS), which serves to identify the different types of actors involved in the biomass value web and the linkages between them. To become a front-runner in the future bioeconomy, the existing innovation network needs to be expanded. In particular, the results highlight the importance of integrating national and international private sector organizations with national public institutions. The findings also suggest that industries need stronger incentives to collaborate with knowledge institutions by overcoming obsolete bureaucratic hurdles and creating incentives for collaborations and exchange. Long-term consistent policies and funding opportunities for risky investments are also required to further strengthen Brazil's innovation network to meet future opportunities and challenges of the bioeconomy.

5.3 Discussion of results

According to the considerations presented in the introductory first chapter, and the empirical results of the papers, this section emphasizes the roles of knowledge, cooperatives and of networks and multi-stakeholder participation. These themes were identified as influential for the development of the bioeconomy from the case studies presented.

5.3.1 The role of knowledge

Two paramount components to the development the bioeconomy are biomass and knowledge. The biomass production potential of Ghana and Brazil are largely recognized (figure 1 p. 13) as the eagles among the chickens, in the story of Dr. Aggrey. However, the combination of the scientists and the local communities' knowledge for the eagle to make use of its strength and fly are necessary. The definition of bioeconomy used in the thesis stresses the importance of knowledge-based production and utilization of biological resources. Considering earlier evidence, for example from the experience of the green revolution in India as well as from the development of the sugarcane sector in Brazil, it is largely accepted that the inclusion of knowledge institutions fosters the uptake and development of innovations.

Brazil is a particularly good example showcasing how investment into knowledge can be successful, especially in the context of the bioeconomy. Government's commitment and the early investment in capacity building and research institutions lead the country to independence from fuel imports and brought about the current comparative advantage in the production of sugar and ethanol (Brazil study; Furtado, Scandiffio, and Cortez 2011; de Moraes and Zilberman 2014). The increase in sugarcane productivity was not driven by subsidies; rather the government had invested in knowledge institutions and fostered the collaboration with cooperatives to develop locally adapted and demand-driven solutions.

Ghana in contrast has not in the same way invested in knowledge institutions but has rather relied on subsidies to close its yield gaps. The subsidy study reveals that this has had little success on maize productivity. State interventions, such as the fertilizer subsidy program, are

justified by demand side failures of smallholder farmers who are not in the position to make use of fertilizers. Common problems are: the lack of financial resources (and access to credit and insurance), and/or the lack of knowledge on how to appropriately use the inputs (or perceive the benefits of them). On the supply side, challenges include: the lack of economies of scale for the private sector to reduce high transport, stocking and distribution cost, which led to the justification of government intervention (Druilhe and Barreiro-Hurlé, 2012). The empirical findings of the fertilizer study identified state failures that do not foster the demand of fertilizer by farmers, such as targeting, rent seeking and elite capture. However, the study also emphasizes the importance of site specific intervention based on multidisciplinary research findings, to address low productivity challenges in the Guinea savanna of Ghana. Agronomic practices, such as improved soil carbon management and reduced mechanical stress through mulching, as suggested by integrated soil fertility management measures are expected to greatly contribute to maize productivity in the study region.

The question arises as to why governments, like Ghana, pursue this strategy even though it is apparently not successful. A possible explanation is that this intervention is more popular among policy makers. Fertilizer subsidy programs are less complex and show higher impact on politician's popularity than complex processes, like investments in agricultural extension, which have lower 'publicity power' (Birner and Resnick, 2010; Jayne and Rashid, 2013). Nevertheless, from a solely economic perspective, by only addressing households that lack knowledge on the benefits of the fertilizer and the poor, development of the fertilizer market would lead to increased fertilizer use through input subsidies (Druilhe and Barreiro-Hurlé, 2012). The study determines that public expenditures would be worthwhile (partly) when allocated to research and extension services.

The importance of political incentives in Ghana can also be seen in the case of cacao, where the nation was able to increase productivity. Major investments, targeted at research and specialized extension services to develop solutions and address problems, were covered by government investments and lead the overall success of the cacao sector. This targeted intervention has been instrumental in strengthening the sector but also in spurring private action (Kolavalli and Vigneri, 2011). From the fertilizer study, one can conclude that a similar effort would be needed to foster increased maize production. Investing in capacity building of local institutions, as for example in equipped laboratories for soil testing is key. Similarly, strengthening research institutions to develop locally adapted solutions, for example to control striga infestations and to support extension services in delivering generated knowledge and report back from the field on problems to be addressed, are important measures to develop the agro-biomass sector. The allocation of public expenditure into extension services are also expected to attract investments from the private sector, as the cases of sugarcane in Brazil and cacao in Ghana have demonstrated. However, it seems that the potential of the eagle has not yet been fully recognized by the local government. The role of this and similar research is to provide the assistance and perseverance of the scientist in the fable.

The role of knowledge was also highlighted in the market queen study. Market queens in Ghana represent an important trader association, which has been overlooked in the value

chain literature. However, it can contribute to strengthening governance, promoting transparent information flows, and increasing participation in local decision-making and mutual (participatory) monitoring of local institutions. The current public discourse has a strong impact on the public perception and the credit cooperatives in Ghana. Integrating these institutions into public debates, and recognizing that their role has the potential to strengthening the information flow between actors, develop community based services and contribute to women's empowerment. Women's empowerment is pivotal for many tangible outcomes, including food security, education, child health, contraceptive use, and is considered overall imperative for achieving poverty reduction and human rights (Allendorf, 2007; Doss, 1996; Hashemi et al., 1996; Jejeebhoy, 2002; Malhotra and Schuler, 2005; Quisumbing and Maluccio, 2000; Schuler et al., 1997; Thomas, 1990).

5.3.2 The role of collective action

The comparative advantage of sugar and ethanol production in Brazil draws attention to the role of cooperatives and their active integration in institutional networks. The coordination between different institutions and farmers was facilitated by cooperatives, as they catalyze knowledge transmission among farmers and research institutions (see Brazil study). Cooperatives and collective action initiatives have the potential to support (small-scale) farmers to compete in the bioeconomy. For example commonly owned processing plants can play a major in the participation of farmers in the new markets. This could be the case of shared biomass digestions units to produce polymers used in the manufacturing of bioplastics of other resources needed in the production of materials in the bioeconomy. Addressing inefficiencies, coordination problems or barriers to access the market is particularly important in developing countries, and forms of collective action can help to address these market failures (Markelova et al., 2009). Collective organizations can foster the development of a well-functioning agro-biomass sector in different ways and from different standpoints in the value chain. The importance of credit cooperatives to overcome governance challenges of small transaction of a risky economic activity by asset poor actors has been addressed in the market queen study.

Transaction costs are the embodiment of barriers that prevent actors in the value chain from interacting. To address these challenges, forms of collective action, such as cooperatives (or market led-female institutions), are helpful in overcoming barriers of assets, information and service (Jaffee, 1995). Cooperatives have the potential to foster income opportunities by reducing transaction costs and facilitate input and product deliveries. They also function as a learning platform; information can be collected at one point and does not have to be retrieved or delivered to become dispersed among members, as highlighted in the market queen study. Moreover, forms of collective action can contribute to positive externalities such as reconciliations between members or actors along the value chain (Boudreaux, 2011). However, there are narratives or myths that have been repeated so many times that they become institutionalized facts (Klein, 2002). This discourse provides what is then experienced as realty (Foucault, 1972). This is the case of female-led credit cooperatives in Ghana, held to be monopolizing market institutions by social consensus. Acknowledging the existence of this discourse and fostering experience exchange on neutral platforms to show a

different aspect of the role of women associations can benefit all actors within the biomass-value web. To foster collaborations however, strengthening collective organizations' immaterial assets such as knowledge, capabilities and uncovering the 'myth' become the main focus. Overall, promotion of social reforms that lead to equity and justices are necessary for traditional institutions to unleash their potential.

The scientist in Dr. Aggrey's story could unravel the eagle's potential because he had a vision and he gained the support of the farmer, who allowed him to prove his narrative wrong, as well as the support of the community who helped him take the eagle to the mountaintop.

Cooperatives channel knowledge and are therefore pivotal to vertical and horizontal information transmission. The accumulated experience in female-led market institutions can trigger other credit institutions to develop strategies to coordinate many members' performing small transactions. Farmer's cooperatives improve access to input and output markets but often lack management skills. For instance, farmers cooperatives in Rwanda have been an important avenue for allowing smallholders to earn more money from coffee and develop additional products, but still lack management and entrepreneurial skills (Boudreaux, 2011). Market queens in Ghana showcase well-functioning credit cooperatives based on strong management and entrepreneurship. The acquired skills and leadership features can serve as models for other cooperatives to address existing market failures.

5.3.3 The role of networks and multi stakeholder participation

The shift towards a bioeconomy requires a form of revolution. Not only the current resource pillars of the industrialized world will need to change substantially, but organizational and social aspects would need to undergo dramatic changes as well (WBGU, 2011). The 'Brenner debate' as introduced in Chapter 1, has initiated the discussion on the role of political and institutional versus technological implantation of innovations. Brenner (1976) advocates for the need to consider institutions when trying to understand what it takes to make an agricultural revolution happen.

The green revolution in India showcases that in addition to technologies that were indispensable to improve yields in a very short time span, vision, leadership, institution-building and multilateral collaboration of diverse actors were crucial aspects for it success. Pivotal was the involvement of research bodies, donor organizations, universities and extension service providers from various levels of global, state, regional, and community centers, which made the green revolution a prominent example of large scale multi-stakeholder collaboration (Banerjee, 2013). The integration of farming communities in this context, as well as scale-neutral technologies that benefited smallholders in particular were was central to the revolution (Akande et al., 2005; Hazell and Ramasamy, 1991; Jewitt and Baker, 2007; Lipton, 1988; Yapa, 1977). Similarly, the comparative advantage of sugar and ethanol in Brazil came about. The military government envisioned the use of ethanol as a substitute to imported gasoline, it created research institutes (1972 Embrapa, the Brazilian Enterprise for Agricultural Research), implemented programs (1975 the National Alcohol Program), and promoted collaboration among stakeholders (de Moraes and Zilberman, 2014).

This thesis argues that the development of the bioeconomy requires a similar effort. Political commitment and networks between institutions are as relevant as the development of biobased products and processes. The Brazil study emphasizes the importance of collaborations between national and international, as well as between private and public sector actors. The results suggest that Brazil has to overcome bureaucratic hurdles and create incentives to foster the innovation system. In the current innovation system in Brazil, coordination and network failures have been identified, for example low intra-industry collaboration (see the adjacency matrix, table 14). However, especially these links are crucial when it comes to facing new challenges, such as technological uncertainty, commercial uncertainty, and the behavioral uncertainty of rival firms (Malmberg et al., 1996). Without links between industries, knowledge generation is slow, expensive and spillover effects might be missed (Buchmann and Pyka, 2014; Pyka and Saviotti, 2002). Suzumura (1992) identifies collaborative R&D networks with rival firms to foster spillovers, and firms are more likely to internalize knowledge spillovers, which once again enhance the incentive to invest in R&D. A recent analysis investigating the industrial cluster projects in Japan found that indirect support programs are even more important than supporting R&D for innovation outcomes. Indirect support programs (participation in meetings and events and using coordination and advisory services) enhances firm performance, this specifically helps the performance of local firms and small to medium enterprises. A closer collaboration in public-private partnerships is also likely to contribute to overcoming current mistrust problems. To avoid crowding out effects, R&D supported by the government needs to also address programs that seems more risky, with less potential for private returns, that would otherwise not be addressed (Hishimura and Okamuro, 2011).

The exploitation of multiple types of knowledge, and the support of the realization of complex multi-institutional links between research activities and the innovation process through both emphasis on the organizational and the institutional dimension is crucial for innovations to come about (Coriat and Weinstein, 2002). In less developed industrial nations similar problems, even if on a different level, “coordination mechanisms need to be given a much more prominent place in policy thinking” (Kydd and Dorward 2004 p. 967). In the rural areas of Ghana for example, government intervention to address coordination failure can intervene through mechanisms to lower risk and increase expected returns. Intervention could attract private agents to invest in multiple points along the supply chain; this might involves communications infrastructure, market information systems, commodity insurance, technical research and extension. Additionally, support for trader and farmer associations to increase basic supply chain profitability should be supported (Kydd and Dorward 2004). The fertilizer study in Ghana identifies low capacity of the extension service to provide knowledge of soil fertility management, and support crop productivity with a locally tailored solution. The case study shows furthermore that the private sector is providing good quality fertilizer but that the distribution stage, carried out by the public sector institution is failing. Similarly, the dominance of public sector institutions in the current seed system in Ghana is facing comparable challenges, even if the context is more complex (Poku et al., n.d.). Aside from political economy aspects, coordination and network failures prevent exploiting the complementary roles of the public and the (national and international) private sector, which

play an important part in the development of the bioeconomy, as indicated in the Brazil study.

As depicted in the fertilizer and the Brazil study, networks and coordination are crucial in the complex bioeconomy development arena. However, dominant narratives, as illustrated in the case of the market queens, are affecting the integration of important traditional institutions. Traditional female-led market institutions are effective in distribution and circulation of information, in particular within the market and among its members, and they successfully coordinate with traditional and government authorities. If integrated in the local institutional network, they could act as agents to diffuse innovations and information on very diverse subjects. Due to the discourse however, their potential is kept at a standstill.

The role of coordination and networks of national and international institutions was even evident in the project itself. BiomassWeb is an interdisciplinary project aimed at making use of the synergies between knowledge fields and different research approaches to develop innovations that are forthcoming for the bioeconomy. However, it has also exemplified how difficult a multi stakeholder and disciplinary approach is. Coordination and poor links between working units can lead to the leaving out of important actors and reduce collaborations to the minimum requirements (by the funding agency). Often these challenges arise due to lack of time and resources, thereby losing the initial well-meant common purpose.

5.3.4 Limitations

To guide similar research in future, limitations of the analytical techniques applied in this research are identified and discussed in this section.

The fertilizer study applied the combination of quantitative household survey data with soil specific parameters, and qualitative focus group discussion tools. The integration of soil parameters in analytical tools conventionally used for socio-economic analysis presented challenges. Due to collinearity problems important element for the development of maize like nitrogen, had to be dropped. However, other critical variables, such as total carbon were included. Furthermore, the soil samples were only taken in the first 20cm of soil; meaning problems of root-penetration ability as limiting factor maybe have been overlooked. The lab analysis of fertilizers revealed a slight discrepancy between labeled and tested nutrient content, higher accuracy could be reached with a second lab testing of the samples, which has not been done. Nevertheless, the small discrepancy did not call for a second round of testing. The regression did not include weather data since the methodological stations in the north of Ghana are limited and in this case were too far away from the surveyed fields. To compensate for this district dummies were included to capture locally differing non-recorded variables.

The market queen study is purely qualitative study based on in-depth interviews. The heated debate on the role of market queen posed restriction for triangulation purposes. However, following principles of grounded theory, the effort to cover all 10 regions in Ghana was undertaken, to observe different typologies of markets and traders across ethnic groups, in order to satisfy data saturation (Glaser and Strauss 1967). In-depth interviews allowed for rich data collection; however the interviews were collected with the help of a translator.

Depending on the eloquence of the translator and the experience of the respondent, the formulation of the question and the additional explanation given to convey the message might have differed. However, member checks were performed to ensure the quality of the information collected. The data and the interpretation of it were continuously tested during the interviews by paraphrasing in clear and simple wording and summarizing for clarification with the respondents. Additionally, peer debriefing was performed during seminars and international conferences, where the findings were presented and discussed. Therefore we are confident, despite the limitations, of the strength of the results.

In the case of the Brazil study, it is worthwhile to note that the data was collected during a period of very low global oil prices, and shortly before a presidential election, both aspects that certainly influenced the respondent's opinion on the development of the ethanol sector. In-depth interviews and a participatory mapping tool, known as Net-Map tool, were applied. The purposive sampling to identify the respondents, based on the sugarcane value-web, could have been affected by selection bias. Especially in the case of international institutions operating in the country, the interviews were often denied therefore not all potential respondents could equally express their position. However, the respondents were chosen because they were knowledgeable about a large variety of actors, and as the data from the interviews was combined, it enabled for triangulation and validation of the information received. The combination of different collection and quality testing approaches compensated for limitations of the single methods (Brewer and Hunter 1989; Guba 1981). Also in this case, the findings were presented and discussed with peers at seminars and international conferences, allowing for validation of the findings.

All three empirical chapters are based on case studies, which per se are limited to certain conditions and time frames. Nevertheless, the insights from the thesis can be important of further analysis and research, as well as to better interpret locally important phenomena.

5.4 Policy recommendations

In pursuit of its goal, the thesis looked at three case studies from two countries at different development stages of the bioeconomy with similar natural conditions, which could theoretically sustain the shift away from the current fossil fuel based economy. The role of policies, institutions and networks has been analyzed to identify underlying governance challenges that prevent better production and utilization of the biomass based resources. Broad policy implications from the research have been identified.

a. Fostering capacity building of research institutions

All three studies clearly underline the need for capacity building of research institutions (see section 5.3.1 "the role of knowledge"). Strengthening local research institutions through laboratory facilities to identify site-specific problems is expected to develop locally adapted solutions. Site-specific data should be coupled with well-trained and well-equipped extension services, as it is expected to address the low maize productivity problem. Equally important are training programs for staff members to foster collaboration with national and international institutions to intensify skills and networks. Policies and regulation should build on intensifying knowledge flows and financially supporting the development of local research

institutions. Allocating a higher share of public expenditures towards capacity building is expected to develop the agro-biomass sector and the bioeconomy with long term effects.

b. Strengthening extension service and addressing region specific problems

The results from the fertilizer study provide evidence for the necessity of strengthening demand driven extension services by addressing regional problems related to production, processing and marketing, as it is necessary to develop the agro-biomass sector. Training of extension officers on locally adapted strategies is pivotal, as well as increasing their budget and equipment availability to reach more remote areas. Providing extension services specialized in 'technological' fields could be considered, as they reduce workload and increase targeting of specific problems (as discussed shortly in the section of the role of knowledge, for the case of cacao in Ghana). The development of a well-structured extension service provisioning system is expected to attract also the private sector and provide wider country coverage, which the Brazil case has demonstrated in the case of the sugarcane sector development.

c. Fostering coordination between research centers, extension service and communities

This study suggests that fostering communication and collaboration efforts between institutions would have an influential effect on overcoming challenges that affect the heterogeneous actors in the innovation system of the bioeconomy. The fertilizer and the Brazil study emphasize the importance of closer networks among research institutions and between research institutions and private and public sector actors. However, the study also highlights the need to better understand local institutions; since it is expected that a successful integration of collective action initiatives could contribute to developments of solutions for wide spread problems, and additionally foster innovation strategies, important for the economy. For example, rural credit systems based on small transactions in a risky environment, as described in the market queen study.

d. Facilitating the integration of collective action groups into institutional networks

The study suggests that cooperatives and other forms of collective action can serve as an effective link to communities in remote areas and possibly amplify the effect of extension service provision. Reinforcing traditional institutions can contribute to strengthening governance in rural areas by promoting transparent information delivery and decision making to represent various groups in the society. Additionally, cooperatives can contribute to strengthening monitoring of institutions and holding them accountable. The case of Brazil depicted cooperatives as effective information channels between farmers and research institutions.

e. Supporting long-term investment schemes and revisiting bureaucratic measures

The study concludes that a strategy to encourage stakeholder participation in innovation networks is through the provision of long-term incentives. Long-term policy perspectives encourage stakeholders to engage in more risky processes, which are vital for the development of the bioeconomy. To attract collaboration across research fields, the obsolete bureaucratic processes, identified in the Brazil study, need to be revisited. The bothersome coordination dimension weakens networks and collaboration, therefore introducing

coordination agents that support interactions in the network should be considered. Coordination institutions can greatly foster the development of the bioeconomy as they can afford to invest time in essential fostering the development of the innovation network.

5.5 Concluding remarks

The case studies from Ghana and Brazil provide a range of insights into the complexity of shifting to a new economic system, from macro-level institutional dynamics to the very inputs that will grow the bioeconomy. Making the bioeconomy a reality will entail vision, leadership and cross-cutting collaboration among diverse institutions. The role of institutions, collaborations and knowledge exchange is paramount, as evidenced by the Green Revolution in India and the first achievements of the bioeconomy in Brazil. As with the story of the eagle among the chickens, these case studies stress that knowledge-based development is vital to unleashing the full potential of the bioeconomy to soar to unprecedented heights.

5.6 References

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Appendix 1

6.1 Soil and fertilizer analyses

In each maize field, three volumetric (318 cm³) soil sample replicates were taken at 0-20 cm depth. The three replicates were dried at 40°C and subsequently pooled, gently disaggregated, and sieved to 2 mm. Soil samples were ground for 2 minutes with a ball mill. Soil samples were analyzed by using a Fourier Transform Infrared spectroscopy (FTIR), a method used to efficiently and quickly predict soil properties at low cost but with high accuracy. FTIR was successfully used to characterize soil characteristics in northern Ghana and central Burkina Faso (Bellwood-Howard et al., 2015). FTIR prediction algorithms were calibrated by reference samples of the present study and additional samples from the same study region. Reference samples were analyzed by conventional methods. The analyzed soil properties reflect common soil factors that potentially limit crop growth. Total C and N were analyzed by dry combustion (Vario EL Elementar Analysesysteme GmbH, Hanau, Germany). Soil pH was measured in $CaCl_2$ solution (1:2.5 w/v). Soil texture was determined by laser diffraction (Analysette 22 MicroTec plus; Fritsch GmbH, Idar-Oberstein, Germany) after treatment with hydrogen peroxide and sodium pyrophosphate. Exchangeable Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} and Al^{3+} were measured by ICP-OES (Ciros CCD, Spectro Analytical Instruments GmbH, Kleve, Germany) after NH_4Cl extraction. Effective CEC ($mmol_c\ kg^{-1}$) was calculated as a sum of the exchangeable cations, accounting for their valence. Exchangeable sodium percentage (ESP; %), i.e. the proportion of sodium from cation exchange capacity, was calculated according to equation 1/A.

$$ESP = \frac{Na}{CEC} \cdot 100 \qquad \text{Equation 1/A}$$

For FTIR analyses, five replicates of each ground sample were transferred to microplates and gently compacted to leave a plain and dense surface for diffuse reflectance measurements in the mid-infrared spectral range (4000 to 500 cm^{-1}). Spectra were recorded with a Bruker Tensor 27 equipped with an automated high throughput device (Bruker HTS-XT, Ettlingen, Germany), according to the method described in Stumpe et al. (2011).

In order to predict soil properties based on FTIR spectra, multivariate calibration functions were established by relating the properties of the reference samples to their spectra using partial least-squares regression in a cross-validation design with the OPUS QUANT software (Bruker, Ettlingen, Germany). If the reference soil data was not normally distributed, they were log or square root transformed prior to calibration. To improve the calibration functions, mathematical spectral pretreatments and exclusion of irrelevant spectral regions were applied with the OPUS quant software. Those combinations of pretreatments and spectral regions which had the lowest root mean square error of cross-validation were chosen for the calibration (Table 15).

Then, the calibration functions were used to predict soil properties of all samples. Due to the exclusion of outliers, the total number of observations with soil variables was reduced to 290. Bulk density was measured for each of the three field replicates. Carbon (C) and nutrients are reported as stocks [kg m^{-2}] by multiplying C and nutrient contents with bulk density and sampled depth after correction for stone contents.

The fertilizer samples were analyzed for total N, P and K contents by means of aqua regia digestion following DIN ISO 11466.

Table 15: Calibration quality indicated by R^2 and root mean square error of cross-validation (RMSECV) of the FTIR analyses of the reference soil samples

Parameter	R^2	RMSECV
C (g/kg)	92.50	0.057
N (g/kg)	89.04	0.061
pH	76.91	0.317
CEC (mmolc/kg)	94.73	0.677
K (mg/kg)	65.35	2.150
Ca (mg/kg)	95.75	2.520
Mg (mg/kg)	71.79	0.139
Na (mg/kg)	61.63	0.415
Silt (%)	73.55	9.540
Clay (%)	59.13	0.128
Sand (%)	75.73	10.300

Reference

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Appendix 2

7.1 Questionnaire household survey

HOUSEHOLD SURVEY

University of Hohenheim

GlobE Project BiomassWeb, WP 6.1 Governance

Study on *Maize Production System, Fertilizer and Seeds in northern Ghana*

Q. Nr. _____

REGION: _____

DISTRICT NAME: _____

COMMUNITY NAME: _____

FARMERS NAME. _____

Enumerator's Name: _____ Date Completed: ____/_____/_____

MODULE 1: General Information

1.1 For how long have you been a farmer? _____

1.2 How many people live in the Household?_____

1.3 How many members in each age group?

no	0-15 years		16-60years		Older than 60	
	Male	Female	Male	Female	Male	Female

1.4 How many members have an education?_____

1.5 How many members work in the field?_____

1.6 Do you have a fertilizer subsidy card/pass?_____ if yes, since when?_____

1.7 Did you received fertilizer at a subsidized price last year?_____

1.8 If yes, how many bags did you buy last year?_____

1.9 How many bags did you buy at full price (without subsidy)?_____

MODULE 2: ASSETS

2.1

HOUSING		LIGHTING	SANITATION	COMMUNITY SERVICES
a. Type of dwelling (current) 1 Several Huts/Buildings (Sar Compounds) 2 Several Huts/Buildings (Dif Compounds) 3 Room(s) (Compound house 4 Single family house 5 Apartment/Flat 6 Others (specify) b. Do other households share this dwelling with you? 1 Yes 2 No c. If yes, how many? _____	d. What is the material of the roof of the house? 1 Mud 2 Thatch 3 Wood 4 Iron Sheets 5 Cement/Concrete 6 Roofing Tiles 7 Asbestos 8 Other (Specify) e. What is the material of the walls of the house? 1 Mud/Mud bricks 2 Stone 3 Burnt bricks 4 Cement/Concrete 5 Wood/Bamboo 6 Iron Sheets 7 Cardboard 8 Other (Specify)	f. What is the main source of lighting for your dwelling? 1 Kerosene Lamp 2 Gas Lamp 3 Candle 4 Torches (Flashlights) 5 Electricity (Mains) 6 Generator 7 Other (specify) g. What is the main fuel used by the household for cooking? 1 Wood 2 Charcoal 3 Gas 4 Electricity 5 Kerosene 6 Other (specify)	h. How does your household get rid of rubbish? 1 Collected 2 Dumped by household 3 Burned by household 4 Buried by household i. What type of toilet does your household use? 1 Flush toilet (WC) 2 Covered pit latrine 3 Uncovered pit latrine 4 Pan/bucket 5 KVIP 6 No toilet (bush) 7 Other (specify) j. Is facility close to the house 1. Yes 2. No k. If no: how far away: _____(in minutes)	l. Do you have the following in your community? 1 School 2 Clinic 3 Transports service

LIVESTOCK

m. Does your household own any livestock?

	ANIMAL	NUMBER OWNED
01	Goats	
02	Sheep	
03	Donkey	
04	Cattle	
05	Pigs	
06	Duck	
07	Chicken	
08	Guinea fowl	
09	Rabbits	
10	Others_____	

OTHER HOUSEHOLD ASSETS

n. Does your Household own any of the following assets?

		Number owned
01	Cutlass	
02	Hoe	
03	Rake	
04	Axe	
05	Shovel	
06	Pick	
07	Sickle	
08	Knap sack sprayer	
09	Trailer/Cart	
10	Donkey cart	
11	Water pump	
12	Irrigation pipes	
13	Tractor	
14	Plough	
15	Harrow	
16	Powertiller	
17	Combine	
18	Grain Storage facility	
19	Milling facility	
20	Others	

2.2 Please tell me about the plots that your household owns or cultivates:

How many hectares /acres of farm land do all household members (people living in the same house) together own: _____ (unit)

Please draw a map with the household location and each plot for the farmer to visualize his plots. Each time he gives an information he can indicate the field he/or you are refereeing to

Land Area Land Unit 1= Acres 2= Hectares 3= Other Please include also plots not under cultivation (fallow)	Who is in charge of cultivation? M= Male F=Female A=All	Crops Currently Grown/planned to grow (2016)?	What type of cultivation did you use? 1=Mono 2= Inter-crop	Last crops grown on plot (2015)	What type of cultivation did you use? 1=Mono 2=Inter-crop	If MAIZE where did you get the seeds from? 1= own from previous year 2=bought at retailers shop 3= from neighbour 4=other (specify)	Did you burn this land before cropping (2015)? 1=yes 2=no	Do you use mineral fertilizer on this plot (2015)? 1=yes 2=no	Do you use manure or crop residues on this plot (2015)? 1=yes 2=no	Please rank the plots for their soil fertility 1=most fertile 2=high/medium 3=medium 4=medium/low 5=low 6=very low same answers possible for different plots	Walking distance to home (minutes)	How often do you visit the plot during rainy season? 1= daily 2= up to 3times a week 4=once a week 5= once a month

1.3 Which crop is the most profitable to grow?_____

MODULE 3: CROP BUDGET MAIZE

3.1 Size of the maize plot_____ (all information are related to only this plot)

	ITEM / ACTIVITY	HIRED LABOUR				FAMILY LABOUR		
		Wage Labour			Contract (indicate, cost in GHC)			
		No. of persons	No. of days	Daily wage/person (GHC)		No. of persons	No. of days	Daily wage/person (GHC)
	A. LABOUR INPUT							
	Manual Land clearing							
	Ploughing (deep tillage)please tick	Animal						
		Tractor						
	Harrowing (surface operation) please tick	Animal						
		Tractor						
	Preparation of the soil with hoes (manual)							
	Planting Date:_____							
	Planting method:	Broadcast ☐	Dibbeling☐	Driling☐				
	Seed variety	Kg Seeds used:	Where did you get the seeds from? 1= own from previous year 2=bought at retailers 3= from neighbor 4=other (specify)		Price of 1Kg:			
	Seed variety	Kg seeds used:	Where did you get the seeds from? 1= own from previous year 2=bought at retailers 3= from neighbor 4=other (specify)		Price of 1Kg:			
	Fertilizer Application	Broadcast ☐	Dibbeling ☐	Ring method☐	Side placement ☐			
	-1st time after planting **date:** _____							
	Type of Fertilizer:				Number of bags:			
	Cost of fertilizer (price of one bag)				Total cos for the plot:			

	HIRED LABOUR				**FAMILY LABOUR**		
	Wage Labour						
ITEM / ACTIVITY	**No. of Persons**	**No. of days**	**Daily wage/Person (GHC)**	**Contract (indicate, cost in GHC)**	**No. of Persons**	**No. of Days**	**Daily wage/ Person (GHC)**
-2nd time after planting **date:_____**							
In case the farmer mixes the **fertilizers** for the second application, please specify for both types of fertilizer:							
Type:	Numbers of bags			Type		Numbers of bags	
Cost of one bag:	Total cost plot:			Cost on one bag		Total cost plot:	
Herbicide Spraying							
-1st time after planting **date:_____**							
Type of Herbicide:				Amount of Herbicide Specify Unit:			
Cost of Herbicide (specify unit):							
-2nd time after planting **date:_____**							
Type of Herbicide:				Amount of Herbicide Specify Unit:			
Cost of Herbicide (specify unit):							
Pesticide Spraying							
-1st time after planting **date:_____**							
Type of Pesticide:				Amount of pesticide Specify Unit:			
Cost of Pesticide (specify unit):							
-2nd time after planting **date:_____**							
Type of Pesticide:				Amount of pesticide Specify Unit:			
Cost of Pesticide (specify unit):							

		HIRED LABOUR				**FAMILY LABOUR**		
		Wage Labour						
	ITEM / ACTIVITY	**No. of persons**	**No. of days**	**Daily wage/person (GHC)**	**Contract (indicate, cost in GHC)**	**No. of persons**	**No. of days**	**Daily wage/person (GHC)**
	Hand weeding							
	-1st time after planting **date:_____**							
	-2nd time after planting **date:_____**							
	-3rd time after planting **date:_____**							
	Harvesting (and Dehusking)							
	Threshing and bagging							
	Transport							
	Fertilizer from shop to farm (GHC/unit)							
	Maize bag from farm to market (GHC/unit)							

	E. OUTPUT VALUE	**Quantity in bags**	**Unit Cost (GHC)**
	TOTAL bags of maize grains (after threshing)		
	Bags from this plot sold at BEST price		
	Bags from this plot sold at LOWEST price		

3.2. For how many seasons did you cultivate maize as on this plot?_____

3.3 Mainly as ☐ monocrop ☐ intercropped

a. if intercropped with which crops:

_____

When planting:

3.4 When planting how many cm to you leave between the plants in the same row_____(cm) and

3.5 how many cm between the rows _____(cm)

3.6 In your opinion what was the main problems of the maize plot last year that affected yield _____

3.7 How severe was striga infestation on this plot in 2015_____**%** (please use chart)

	Very Serious Problem	**Serious Problem**	**Moderate Problem**	**Minor Problem**	**Not a Problem At All**
Lack of rainfall	5	4	3	2	1
Poor soil quality	5	4	3	2	1
Fertilizer response of plants	5	4	3	2	1
Flooding	5	4	3	2	1
Seed quality	5	4	3	2	1
Animal disturbance	5	4	3	2	1
Plant diseases	5	4	3	2	1
Pests	5	4	3	2	1
Striga (bochaa)	5	4	3	2	1
Other weeds	5	4	3	2	1
Bush fires	5	4	3	2	1
Other	5	4	3	2	1

MODULE 4: CONSTRAINTS

If the household <u>did NOT use purchased inputs</u> during the past season:

4.1 Where is the next location where the following inputs are available?_____and distance in Km_____(if possible)

Input	Did you ever use this input before? **1=yes** **2=no**	If **NO** , why not? 1= Not profitable 2= Too expensive 3= Low quality 4= I don't trust the quality 5= Distance/ Transport	If **YES** , why did you stop using it? 1= Not profitable 2= Too expensive 3= Low quality 4= I don't trust the quality 5= Distance/Transport
Improved maize seeds			
Fertilizer			
Herbicides			
Pesticides			
Mechanization (tractors, irrigation, animal draught power…..)			

MODULE 5: MARKETING

5.1 How many bags of maize did you produce in total in 2015?_____

5.2 How many bags were used for own consumption?_____

5.3 How may bags were sold?_____

5.4 Please fill this table on maize marketing 2015

Crop	Who is your main buyer? **Buyer code**	What amount was sold at farm gate?	What amount was taken and sold in the market?	If yes, which were the major reasons to choose your buyer? **Choice code**	Did you have information about the prices of other buyers? 1=yes 2=no
Maize					

Buyer Code:1 = Private trader, 2 = Farmer cooperative or association, 3 = Consumers (including Relative/Friend) 5 = NGO, 6 =Government (agric) 8= Other (Specify):_____

Choice code: 1= convenient location 2= I trust the buyer 3=better price 4=contract 5=received loan from him/her 6= convenient location 7=other (specify): _____

5.5 List your three biggest constraints to increase your income from crop production.

Constraints to the production	Please rank them regarding their importance **(1 being the most important)**

MODULE 6: MAJOR CHALLENGES

6.1 In general, how important are each of the following problems for farmers like yourself?

	Very Serious Problem	Serious Problem	Moderate Problem	Minor Problem	Not a Problem at All
Can you easily increase your land owning	5	4	3	2	1
Is the quality of the soil a problem	5	4	3	2	1
Costs of plant production	5	4	3	2	1
Can you easily get credit	5	4	3	2	1
Can you buy inputs whenever you need them	5	4	3	2	1
Can you get labor when need it	5	4	3	2	1
Can you control pest and diseases	5	4	3	2	1
Is the quality of the fertilizer a problem	5	4	3	2	1
Do you see the weather as a problem	5	4	3	2	1
Do you experience harvest losses wile storing	5	4	3	2	1 (e.g. thought pests or molt)
Issues addressed by extension service are too few	5	4	3	2	1
Extension service taking place to seldom	5	4	3	2	1
The quality of training on farming is poor	5	4	3	2	1
Can you get a good price for your crops	5	4	3	2	1
Is marketing a problem (transport, finding a buyer)	5	4	3	2	1
Do you get paid immediately	5	4	3	2	1
Is instability of prices a problem for you	5	4	3	2	1
Do you receive lower prices due to poor quality	5	4	3	2	1
Can you produce more if needed	5	4	3	2	1
Can you easily join or form a farmers group	5	4	3	2	1

MODULE 7: INNOVATION AND EXTENSION

7.1. When did you received training last time on farming practices_____ (in month or years)

On which CROP did you receive training/advice on crop production?	Who provided this training and/or advice? USE Org.CODE!	What was the advice given by the extension service officers? USE topic code or specify	Did you have to pay for it? 1= Yes 2=No	Have you been able to apply the technology? 1= Yes 2=No	Did your yield improved with the application of this technique? 1= Yes 2=No

Org. Code: 1= Government (MoFA), 2= Private Sector (e.g. buyers), 3= NGO´s (e.g. Masara N`Arziki…), 4= FBO´s, 5= Other (specify_____)

Topic Code: 1= Use of improved seeds 2=Application of fertilizers 3= Use of manure/crop residues 4= Application of chemicals 5= Plant in rows 6=Planting distance 7= Post-harvest handling 8= Processing 9= Marketing 10= Workers safety 11= Others (specify_____) 12=Planting method

7.2 What topic you would like to get training on?

_____

_____

_____

7.3 During the past years, did you start to use some new farming practices in **MAIZE,** such as a new variety, new cultivation method, soil fertility/ fertilizer/ pest management technique etc.?

☐ Yes ☐ No

If Yes,

New practice adopted	From whom did you get the information about this practice? **Info code**	Did adoption of the new practice involve costs? 1=Yes 2=No	If yes, for what? 1=purchased inputs 2=labour 3=Other _____	Did adoption of new practice require more labour input? 1 = Yes 2 = No	Did you see an increase in yield 1=Yes 2=No	Will you continue this practice? 1=Yes 2=No	If no, why not? **Discontinuation code**

Info code: 1=MOFA extension agent; 2=other farmer; 3=input dealer; 4= maize buyer; 5=radio; 6=NGO; 7=other_____

Discontinuation code: 1=too expensive, 2= not profitable, 3=too much labour needed, 4=inputs not available any more, 5=no market, 6=other: _____

I would like to thank you for your time and effort in completing our survey. The information you have provided will be extremely valuable to our research!

MODULE 8: PLOT AND SOIL DATA

Plot/Household ID: _____

GPS waypoint household/community _____

Walk around plot for area measurement _____acres

GPS waypoint plot: _____

Site characterization

If plot is very heterogeneous in terms of plant cover (trees, different crop residues), soil color (dark-light/red-yellow-brown), rock outcrops, topography or paths, please draw a plot map, indicating the borders

Topography

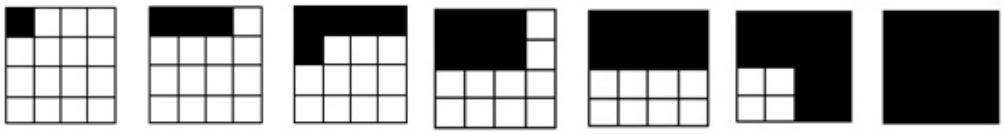
□ uniform □ heterogeneous

8.5 If sloping land, Plot position on slope □ top slope □ middle slope □ foot slope

8.6 Overall slope steepness: □ flat □ slightly sloping □ sloping □ steep

Soil color 8.7 Uniform in whole plot □yes □ no

8.8 if yes, Strong differences in soil color are: □ dark-light □ red-yellow-brown □ other: _____ **Ground cover**



- 10% -20% -30% -40% -50% -75% -100%

8.9 Estimated tree cover (in %): _____ [0 if none] **8.10** Est. amount of trees: _____ [0 if none]

8.11 Estimated ground cover of rock outcrops (which make crop cultivation impossible) in %:_____[0 if none]

8.12 Estimated ground cover of any other obstacle which inhibit crop growth (in %):_____ [0 if none]

8.13 **Signs of soil erosion** □ Gullys □ rills □ soil pillars. □ soil buildup/sediment fans □ other: _____

8.14 **Tillage system** □ Beds □ Plane □ Other: _____

8.15 □ Ridge/furrow: Distance of ridges (m): _____ [note distances measured at three points]

8.16 □ heaps: Distance of heaps (m): left/right_____ top/down:_____ [distances measured at 3 points]

8.17 **Planting density** (m) of previous maize **if still visible**: left/right _____ top/down: _____ [distances measured at three points]

Crop residues other than maize which were found in field:
_____

Plot ID	**Fresh weight (g)**	**Comments (unusual observations e.g. sampling depth if other than 20 cm)**
Soil sample #1		
Soil sample #2		
Soil sample #3		
Mixed sample		
Mixed dry		

[i]