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Is Africa ready to develop a competitive bioeconomy? The case of the cassava value web in Ghana

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ABSTRACT

The increasing global demand for diverse biomass-based products such as food, feed and fuel can transform African agriculture from a food-supplying to a biomass-supplying and processing sector in the growing international bioeconomy. This study addresses the requisite policy and institutional environment needed to foster the development of a competitive and sustainable bioeconomy in Africa. The paper uses the case of cassava in Ghana for an empirical case study. The novel concept of biomass-based value webs, that is, interlinked agricultural value chains, is combined with Porter's Diamond model to analyse the extent to which Ghana is positioned to develop a competitive cassava value web. Empirical data collection involved mapping the physical biomass flows, applying the 'Net-Map' tool to identify all the actors in the emerging value web and their linkages, as well as in-depth interviews with the identified actors. The study finds that despite the huge opportunities for cassava biomass in Ghana, there are coordination problems between farmers, processors and industrial end-users. This has hindered the potential for increased cassava production, processing and utilisation. There is also generally a lack of private sector initiatives in the development of new cassava based products. Accordingly, industrial end-users tend to depend on imported alternatives. Unsuccessful government initiatives and the absence of legislation such as a composite flour policy or a biofuel blend policy have also been major contributing factors to the unrealised industrial potential of cassava in Ghana. The findings therefore suggest that competitive cassava utilisation in the emerging bioeconomy hinges on stronger institutional linkages between value web actors and government support mainly in the form of local content policies that encourage the use of cassava based products.

1. Introduction

The primacy of food security in crop production in Sub-Saharan Africa cannot be denied. However, there is also increasing global demand for other biomass-based products such as feed, fuel and fibre (Timilsina et al., 2012). This trend can transform African agriculture from a food-supplying to a biomass-supplying and processing sector in the growing international bio-based economy (bioeconomy) (Virchow et al., 2016). Biomass-rich African countries, most of which are agrarian-dominated economies, are gradually beginning to recognise the economic potential and sustainability of such a transition. Development of a bioeconomy in Africa can promote economic growth by diversifying the markets for agricultural commodities whiles also reducing dependence on imports of oil and intermediate inputs. This would generate employment and income, particularly in rural areas. The demand-pull would also stimulate increased agricultural productivity thereby ensuring food security (Abass, 2014). Countries like Malawi, Tanzania, Ethiopia and Ghana have started engaging in some bioeconomic activities based on various feedstock crops (see Acheampong and Campion, 2014; De Groote et al., 2013; Jumbe et al., 2009). However, the existing institutional framework in African countries often does not enable the optimal and sustainable exploitation of these emerging and potential opportunities.

This paper addresses the requisite policy and institutional environment needed to foster the development of a competitive and sustainable bioeconomy in Africa. Currently, many studies related to the development of the emerging bioeconomy in Africa tend to focus more on the needed agronomic or technological

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innovations (see eg. Adekunle et al., 2016; Batidzirai et al., 2016; Tui et al., 2015). However, a sustainable bioeconomy development strategy is not confined to these types of innovations alone but equally requires a conducive policy environment and broad-based institutional innovations.

The augmented diversity of activities in the evolving bioeconomy strengthens the interlinkages between the production, processing, utilisation and trading of both food and non-food biomass. This includes the cascading use of biomass as well as the use of by-products. This leads to complex systems of merged or interlinked biomass value chains (Virchow et al., 2014). For instance, sugarcane biomass in Brazil is used for a wide range of bio-based products, including food (sugar and related products), bioenergy (ethanol, bioelectricity), bio-based bulk materials (bioplastic) as well as bio-based high value products (e.g. flavours and fragrances) (Scheiterle et al., 2018). Hence in such a system, the conventional product-focused linear value chain approach is not sufficient to analyse the complex pathways of biomass flows. To better understand the development of the bioeconomy, there is therefore the need to utilise new tools and concepts.

Using the case of cassava (*Manihot esculenta*) in Ghana as an empirical example, the paper makes two contributions to the bioeconomy literature. First, the paper applies the novel 'biomass-based value web' concept to provide a more holistic analytical approach to understanding the linkages between several agricultural value chains and how they are governed (Virchow et al., 2016). This concept is combined with Porter (1990) Diamond model of national competitive advantage to identify the policies and institutional factors that are relevant for developing an internationally competitive value web. Second, the study highlights the potential of cassava as an important crop in the emerging bioeconomy. Cassava is a perennial starchy crop that has the advantage of being able to grow under marginal production conditions (Pandey et al., 2000). The potential high yields of starch and total dry matter even under such conditions make cassava one of the most attractive bioeconomy crops with multiple usages (Abass et al., 2011; Jansson et al., 2009). Yet, it has received less attention in the literature than other bioeconomy crops like maize, oil palm and sugarcane (e.g. see Scheiterle et al., 2018; Umar et al., 2013; Goldemberg and Guardabassi, 2009).

In Ghana, cassava biomass is increasingly serving as a raw material for bio-based products such as starch, industrial flour, ethanol and feed formulations (see Poku et al., 2018). Ghana has been the sixth largest producer of cassava globally and the third largest in Africa over the last decade (FAOSTAT, 2017). Cassava is a major food crop in Ghana, as in other parts of Africa. Fresh cassava roots and traditionally processed products are widely sold in domestic markets. Cassava leaves are also consumed in some parts of the country. However, there has recently been increased recognition of the industrial potential of cassava biomass (Kleih et al., 2013). The country's annual food balance sheet consistently shows approximately 30% surplus in cassava production (MoFA, 2015a; MoFA, 2014). Most of this produce goes to waste (Naziri et al., 2014). This presents a viable starting point for establishing alternative value chains without affecting food security.

Three data collection methods were combined for the empirical application of the concepts of the biomass-based value web and the Diamond model: mapping the physical biomass flows, the relatively new participatory mapping tool known as Net-Map (Schiffer, 2007) and expert interviews. Social network analysis and content analysis are used to analyse the data. The study finds that despite the huge opportunities for cassava biomass in Ghana, there are coordination problems between farmers, processors and industrial end-users. This has hindered the potential for increased cassava production, processing and utilisation.

The rest of the paper is organised as follows: Section 2 highlights the development of the cassava sub-sector in Ghana. Section 3 develops the conceptual framework used for the study. Section 4 describes the research methods. The empirical results are presented in Section 5 and subsequently discussed in Section 6. Section 7 concludes by summarising the study's main findings.

2. The cassava sub-sector in Ghana

Cassava is a major staple crop in Ghana that has seen a steady increase in annual production since the 1990s. Ghana is self-sufficient in cassava production and the crop is very important in terms of caloric intake and per capita consumption in the country (Angelucci, 2013). As shown in Table 1, Ghana was the sixth largest producer of cassava globally and the third largest in Sub-Saharan Africa between 2000 and 2014. However, Ghana was the fourth most productive producer over the period, behind Thailand, Indonesia and Vietnam where cassava is mainly grown as an industrial crop.

The early 1980s marked a shift in the image of cassava in Ghana from a famine-reserve crop to a staple crop due to its food security benefits. This shift was facilitated by government investment in the dissemination of disease-resistant improved cassava varieties developed by the International Institute of Tropical Agriculture (IITA) to increase productivity (Nweke, 2004). More recently, the Food and Agriculture Sector Development Policy (FASDEP) developed in 2002 and revised in 2007 signaled continued commitment from the government to increase farm productivity in the sub-sector for food security. These efforts have been greatly supported by donor-funded programmes such as the Root and Tuber Improvement and Marketing Programme (RTIMP) and the West African Agricultural Productivity Program (WAAPP). As of 2010, twenty-one improved cassava varieties had been developed and released in Ghana (Alene et al., 2015). However in 2001, a Presidential Special Initiative (PSI) on industrial cassava starch production for export was also introduced. This was one of similar initiatives undertaken in other cassava producing countries in Africa, supported by the New Partnership for Africa's Development (NEPAD) Pan-African Cassava Initiative (see Anga, 2008). The initiative involved the establishment of the model government-owned starch processing factory, Ayensu Starch Company. This PSI was ultimately unsuccessful at tapping into foreign markets due to numerous operational challenges of the factory (Angelucci, 2013). Nonetheless, the PSI raised awareness of the commercial and industrial potential of cassava.

Approximately 50% of all harvested cassava roots are still consumed as freshly cooked tubers (FRI, 2012). However, there are an increasing number of small and medium scale enterprises that are now producing packaged forms of traditional foods like *gari* (granulated roasted cassava) for both the urban domestic and foreign markets (van Rheenen et al., 2012). The use of high quality

Table 1
Top cassava producers globally, 2000–2014.

Country	Average Annual Production (1000 t)	Average Annual Yield (t/ha)
Nigeria	41,824	9.91
Brazil	24,208	13.91
Thailand	23,412	20.20
Indonesia	20,696	17.29
Democratic Republic of the Congo	15,027	8.10
Ghana	11,640	14.27
Angola	9678	12.16
Vietnam	7319	16.17

Source: FAOSTAT (2017).

cassava flour (HQCF), the development of which was spearheaded by IITA, has also gained traction in some industries (Abass et al., 2011). Bakeries and institutions such as secondary schools and hotels have been using HQCF as a compliment to wheat flour for baking bread and other bakery products (Kleih et al., 2013). Plywood companies are similarly using industrial grade cassava flour, which is of lower quality than food-grade HQCF, as a glue extender in place of wheat flour (Koyama et al., 2015). Cassava is also being used to produce beer for the domestic market (MoFA, 2015b).

Cassava leaves and tuber peels are mainly used as supplementary animal feed in Ghana. However, cassava leaves are also consumed by some segments of the population, most notably in Northern Ghana (Opoku-Nkoom et al., 2013). In the pig industry, concentrated in the forest zone of the country, cassava roots are also increasingly being used in feeding rations in various forms such as dried chips and grits, flour and cooked roots (Kleih et al., 2013).

The diverse use of cassava biomass and the derived products and by-products have high potential utility in different end-user markets. The development of these new cassava value chains demonstrates the growing importance of cassava in Ghana to food security, employment and wealth creation.

3. Conceptual framework

The conceptual framework of the study consists of two parts. First, the concept of biomass-based value webs is explained. Subsequently, the Diamond model is applied to guide the empirical investigation of the competitive advantage of Ghana's cassava value web.

3.1. The biomass-based value web concept

Biomass is a term used to describe organic matter that is derived from plants and animals. Agricultural crops and their residue are therefore a rich source of biomass. A bio-based economy or bioeconomy is a knowledge-based system of producing and transforming such biomass resources into economically competitive products in new, sustainable and eco-efficient ways so as to capture an increasing share of added value across all economic sectors (Global Bioeconomy Summit, 2015; OECD, 2008). These processes effectively strengthen the link between biomass production, utilisation and trading. Accordingly, 'biomass-based value webs' are complex systems of interlinked value chains in which food, feed, fuel and other biomass-based raw materials are produced, processed, traded and consumed (Virchow et al., 2016).

The value web concept was developed by Virchow et al. (2016) as an extension to Porter (1985) classical value chain concept to capture the multiple pathways and uses of biomass in the bioeconomy. The web perspective serves as a multidimensional framework that facilitates exploration of both the synergies and bottlenecks in and between interrelated value chains (Smith et al., 2000). This approach also importantly accounts for recycling processes and the cascading effects of biomass utilisation which not only merges value chains but also closes material cycles in a system of 'zero waste' biomass (Virchow et al., 2016). This emphasises the synergies between different biomass uses. Scheiterle et al. (2018) aptly used this approach to assess the multiple uses of sugarcane biomass in Brazil's bioeconomy. Similarly, the value web concept is used in this study to analyse the physical flow of biomass as well as the actors involved in production, processing, trade and use of the biomass and the products and by-products that are derived from it.

The biomass-based value web concept therefore provides a holistic analytical approach to understanding the increasingly complex pathways of cassava biomass flows in Ghana and how this system is governed, whiles also highlighting the potential for innovation.

3.2. Applying the Diamond Model

In order to develop a sustainable and efficient biomass-based value web in the emerging bioeconomy, the production, processing and utilisation of biomass must be competitive. Therefore, Porter (1990) Diamond model is applied to analyse the national competitiveness of the cassava value web in Ghana.

The Diamond Model defines four broad attributes that determine the competitive advantage of nations or industries. The framework allows for the assessment of why certain industries based in some countries are able to innovate faster than other industries as well as international competitors. As shown in Fig. 1, the four interrelated determinants of competitive advantage proposed by the Diamond Model are factor conditions, demand conditions, firm structure and strategy, and related and supporting industries. The model also considers the role of the government in acting as a catalyst to improve a country's position in a globally competitive economic environment. The dynamics of national competitive advantage also effectively creates clusters of competitive industries that are linked by different types of interactions (Porter, 1990). The Diamond model has been appropriately used in analysing the national competitiveness of different agricultural industries and value chains (see Sterns and Spreen, 2010; Neven and Dröge, 2001).

In this paper, the Diamond Model is combined with the concept of biomass-based value webs to identify the linkages between all the actors involved in the value web and thereby analyse the competitive advantage of Ghana's cassava value web. The financial, knowledge and business interactions between the different stakeholders are therefore assessed. The analytical goal is to identify the extent to which Ghana is positioned to make use of new opportunities and develop a competitive cassava value web in the emerging bioeconomy.

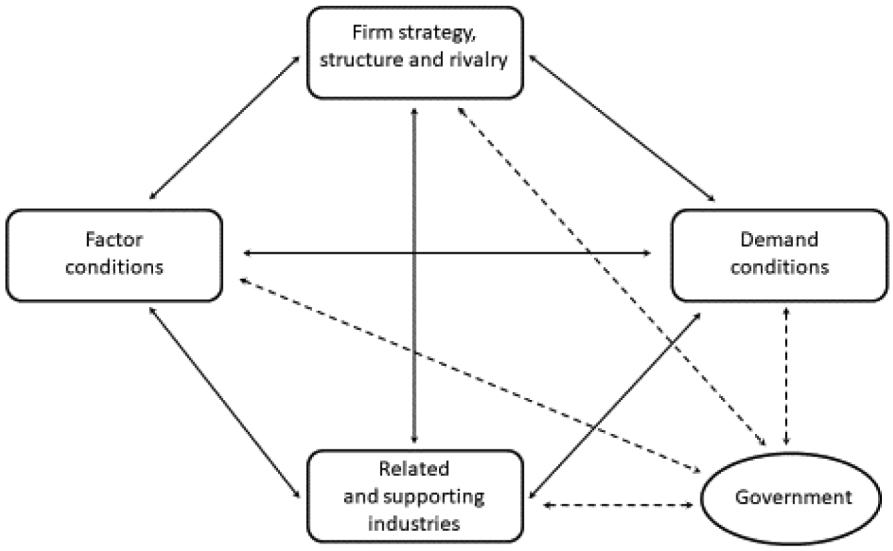
4. Research methods

This section presents the research design of the study followed by the data collection methods used for the study.

4.1. Research design

A three-step approach was used to collect data for the study. In the first step, the cassava value web was visually mapped out with purposively sampled experts. These respondents were selected based on their extensive experience and knowledge of Ghana's cassava value web. The visualisation of the value web involved identifying all the existing products and cascading uses of cassava biomass in Ghana as well as potential future derivatives from the crop biomass. This information was cross-checked from the existing literature and through direct observation (e.g., of various processing activities). The map produced was also used as the initial means of identifying the actors in the cassava value web.

In the second step, the Net-Map tool was applied. Net-Map is a participatory social network mapping tool based on the visualisation of networks within multi-stakeholder systems by respondents (Schiffer, 2007). The tool was used to identify all the actors in the cassava value web and to assess how they are linked. Guided by the mapping exercise in the first step, the Net-Map exercise was carried out with purposively sampled respondents who had an in-depth understanding of how the entire cassava value web operates. A detailed description of how this tool was applied is explained in Section 4.2.



Source: Porter (1990)

Fig. 1. Porter's Diamond model of national competitive advantage.

The final step involved in-depth interviews with selected experts from all the identified stakeholder categories from the Net-Map exercise using purposive sampling. These respondents were selected on the basis of having a high level of experience and expertise in carrying out specific functions in the cassava value web. Additional in-depth interviews were conducted using chain-referral sampling to ensure exhaustive expert information. The respondents included donors, public research institutions, government agencies, processors, farmers and other stakeholders across the country. A total of 47 respondents were involved in the study (see Table 2). Each interview was semi-structured and open-ended with the aim of best capturing the respondent's expert opinion on the challenges and opportunities of a cassava based bioeconomy. Member checks in the interview process involved paraphrasing or restating responses from respondents for clarification where necessary (see Guba and Lincoln, 1989). The three-step research design was complemented with an extensive review and synthesis of relevant policy documents and project reports. The document review served as triangulation to validate the reliability of the findings.

4.2. Data collection

Data collection was carried out between October 2015 and April 2017. The exercise of mapping out the physical flow of cassava biomass and its products was carried out with three respondents. These respondents represented government agencies, public research institutions and medium and large scale processors.

The Net-Map tool was applied with six respondents from different stakeholder categories in the cassava value web. The respondents included those from the initial mapping exercise. The application of Net-Map involved four steps: (1) The respondents were asked to identify all the actors involved in the cassava value web and their respective roles. These actors were recorded on a large sheet of paper. (2) The respondents were asked to identify the fund flows, knowledge flows and business linkages between the different actors. One-sided arrows were used for linkages that were unidirectional while double-sided arrows were used for two-way linkages between actors. Different colors were used to distinguish the three types of linkages. Fund flows were defined as money or financing meted out for particular activities; knowledge flows were considered as linkages involving the transfer of information, technical know-how, training and capacity building; business linkages were defined as transactions involving the exchange of goods and services (service delivery). (3) After completion of the map, respondents were asked to review whether all the actors and linkages in the value web had been included. (4) Finally, follow-up questions were asked on the challenges and opportunities in the cassava

Table 2
Overview of expert interviews.

Stakeholder Category	Number of Value Web maps	Number of Net-Maps	Number of Interviews (including Value Web maps & Net-Maps)
Development Partners/Donors			1
Government agencies	1	1	6
Public research institutions	1	2	8
Financial institutions			1
Industrial end-users			7
Supporting actors		1	5
Micro-processors			3
Medium & large scale processors	1	2	7
Farmers			6
Traders			3
Total	**3**	**6**	**47**

value web. This included asking respondents to identify any additional actors who had not been considered in the Net-Map that could potentially play an important role in the development and production of cassava based bioeconomy products. The visualisation of the stakeholders of the value web in the form of the Net-Map in front of the respondent facilitated the identification of these challenges and opportunities.

The subsequent interviews mainly focused on the challenges and opportunities related to respondents' specific activities in the value web. The interviews also served as a means of validating the fund flows, knowledge flows and business linkages of the actors established from the Net-Map exercises. The Net-Map exercises and in-depth expert interviews were conducted in person on a one-on-one basis at the convenience of the respondents. All the interviews of the study were audio-recorded with the expressed permission of the respondents.

4.3. Data analysis

A combination of qualitative and quantitative methods was used to analyse the data collected. The recorded in-depth interviews were inductively analysed using content analysis to identify recurring and unique themes (see Berg et al., 2004; Glaser and Strauss, 1967).

The networks identified during the Net-Map exercises were analysed quantitatively using social network analysis. There were no contradictions in the information provided by the respondents in the Net-Map exercises. However, some of the Net-Maps varied in the level of detail in terms of the number of stakeholders and linkages. The lack of contradictions facilitated aggregation of the 6 Net-Maps. The UCINET software (Borgatti et al., 2002) was used to derive statistical measures of centrality (degree, closeness and betweenness) among the actors.

Degree centrality shows the number of links an actor has compared to other actors in a network (Borgatti, 2005). Therefore, an actor with a higher value has a larger number of interactions with other actors in a given network and is considered more influential. In the estimations of degree centrality, outgoing and incoming links from an actor are presented as (Out)Degree and (In) Degree respectively.

Closeness centrality measures the average number of links an actor needs to reach other actors in a network (Freeman, 1978). Thus, actors who were unconnected were not included in this calculation. A higher value depicts the more central or interlinked an actor is in a network and the closer that actor is to all other actors. In the estimations of closeness centrality, outgoing and incoming links from an actor are presented as (Out)Closeness and (In)Closeness respectively.

Betweenness centrality quantifies the number of times an actor acts as an intermediary along the shortest path between two other actors in a network. A higher value indicates a higher frequency of an actor's role as an intermediary between two other actors (Borgatti, 2005).

5. Results

This section begins by presenting the graphical representation of biomass flows in the cassava value web. Afterwards, the empirical findings of the social network analysis and the challenges and opportunities of developing a competitive cassava value web are presented.

5.1. The cassava value web

The map of the cassava value web illustrated in Fig. 2 identifies all the cascading uses of cassava biomass in Ghana. The map also

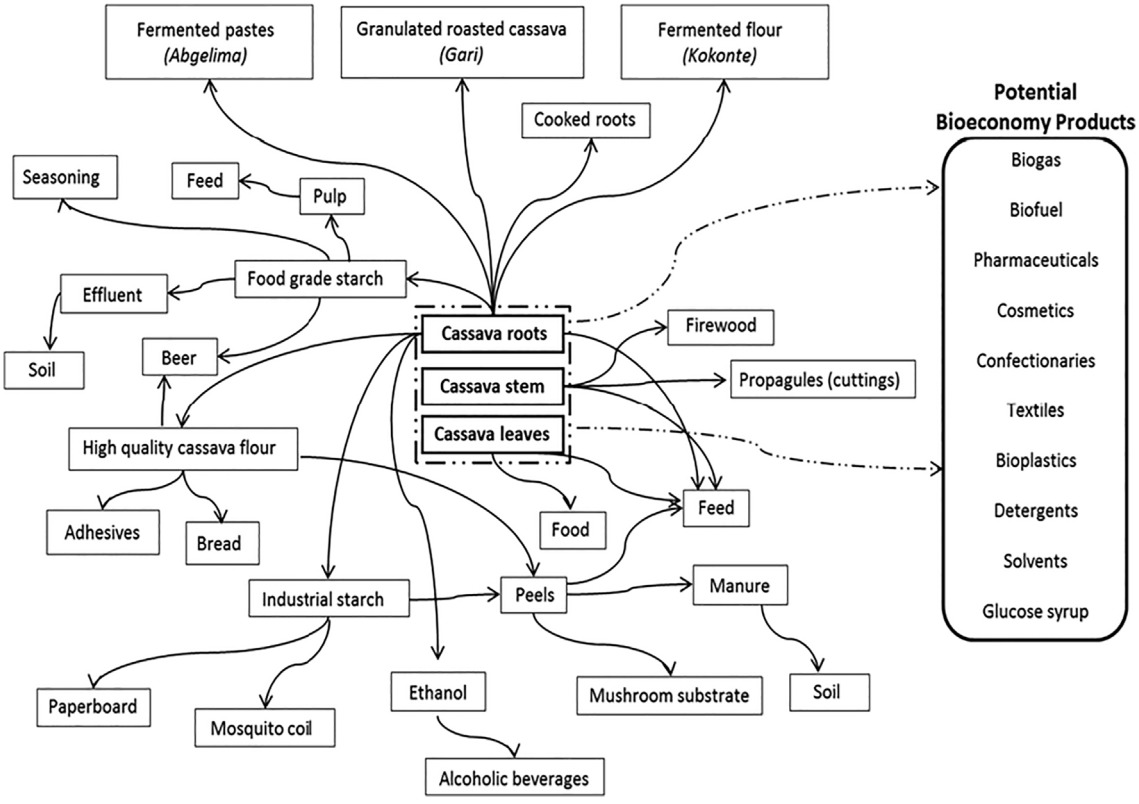


Fig. 2. Biomass flows in the cassava value web.

considers the most realistic potential uses of the crop biomass as envisaged by industry experts.

5.2. Actors and their roles in the cassava value web

The results from the Net-Map exercises revealed that the World Bank, the International Institute of Tropical Agriculture (IITA), the Food and Agriculture Organisation of the United Nations (FAO), the Bill and Melinda Gates Foundation (BMGF) and the International Fund for Agricultural Development (IFAD) are the main funding institutions of projects and programmes in the value web.

Smallholder farmers serve as the main source of cassava biomass. However more recently, there are a few commercial cassava producers in Ghana. Micro-processors specialise in processing cassava into traditional foods. Medium and large scale processors on the other hand are involved in processing both food and industrial products. Traders are the main outlet for the sale of fresh cassava roots and processed traditional foods. Most micro-processors are also traders.

The Ministry of Food and Agriculture (MoFA) is the primary government agency responsible for the growth and development of the cassava sub-sector in Ghana. The Ghana Regional Appropriate Technology Industrial Service (GRATIS) is also a public institution that designs and manufactures cassava production and processing equipment.

Public research institutions are the driving force of innovation in the value web. The Crop Research Institute (CRI) and the Savannah Agricultural Research Institute (SARI) are mandated to breed improved cassava varieties suitable for the different agro-ecologies. The Institute of Industrial Research is responsible for scientific and technological research into industrial equipment and processes. The Soil Research Institute focuses on the utilisation and management of the soil resources of Ghana for increased and sustainable cassava production. The Food Research Institute is responsible for market oriented research of cassava's various food uses. All of these institutions fall under the umbrella of the Council for Scientific and Industrial Research (CSIR). The public universities collaborate and complement the output of these public research institutions. For instance, 3 improved cassava varieties have been bred by public universities.

The main financial institutions involved in the cassava value web are commercial banks and microfinance institutions which offer short and medium term financing to farmers and processors. The Outgrower and Value Chain Fund on the other hand is a German funded programme for outgrower schemes that offers long term financing. EximBank is a public development bank that funds enterprises in the export business.

There are a number of end-users that are increasingly utilising and selling cassava based products. They include bakeries, piggeries, plywood manufactures, packaging companies and breweries. Finally, there are other supporting actors such as input suppliers that mainly sell herbicides to cassava producers; aggregators buy fresh roots from numerous dispersed smallholders and sell in bulk to medium and large scale processors; fabricators are private entities that compete with GRATIS in designing and manufacturing cassava processing equipment; the industrial cassava stakeholders' platform is a platform of actors in the value web that aims to link farmers and processors to industrial end-users and advocates for favourable government policies to support industrialising cassava in Ghana.

The 29 institutions identified in the cassava value web can be grouped into 7 clusters as shown in Table 3.

Table 3
Clusters of actors in the cassava value web.

Clusters	Institutions
Development Partners/Donors	World Bank
	IITA
	FAO
	BMGF
	IFAD
Cassava sub-sector	Farmers
	Micro-processors
	Medium & large scale processors
	Traders
Government agencies	Ministry of Food & Agriculture
	GRATIS
Public research institutions	CRI/SARI
	Institute of Industrial Research
	Food Research Institute
	Soil Research Institute
	Universities
Financial institutions	Outgrower & Value Chain Fund
	EximBank
	Banks & microfinance institutions
Industrial end-users	Bakeries
	Piggeries
	Supermarkets
	Breweries/Distilleries
	Plywood manufacturers
	Packaging companies
Supporting actors	Stakeholders' platform
	Fabricators
	Input suppliers
	Aggregators

5.3. Institutional linkages in the cassava value web

The results of the social network analysis display the institutional linkages between the actors in the cassava value web in terms of the fund flows, knowledge flows and business linkages.

5.3.1. Fund flows

Fig. 3 shows the network of fund flows in the cassava value web. It is evident that the network is highly dependent on donor funds. MoFA serves as the focal institution that directly receives and disperses most donor funds to other actors in the value web. Therefore, MoFA controls most of the funds in the network. Public research institutions such as the Food Research Institute and CRI/SARI are the only other actors that receive direct funding from development partners. However, these institutions also receive funds from MoFA.

Apart from MoFA, banks and microfinance institutions as well as medium and large scale processors are the only two other actors who play an intermediary role in the funding network. Interestingly, farmers do not receive any direct funding from banks and microfinance institutions in the network. They rather depend on medium and large scale processors and MoFA. These findings are also indicated by the centrality measures (see Appendix 1).

5.3.2. Knowledge flows

Fig. 4 shows that knowledge flows are significantly dispersed among public and private institutions in the value web. Most of the actors in the network both transfer and receive knowledge. It must however be noted that a number of actors including banks and microfinance institutions, traders and some industrial end-users are isolated in the network (see Appendix 2).

The Food Research Institute is the most connected actor in the network, followed by MoFA and the universities respectively. These public institutions serve as the main sources of new knowledge for

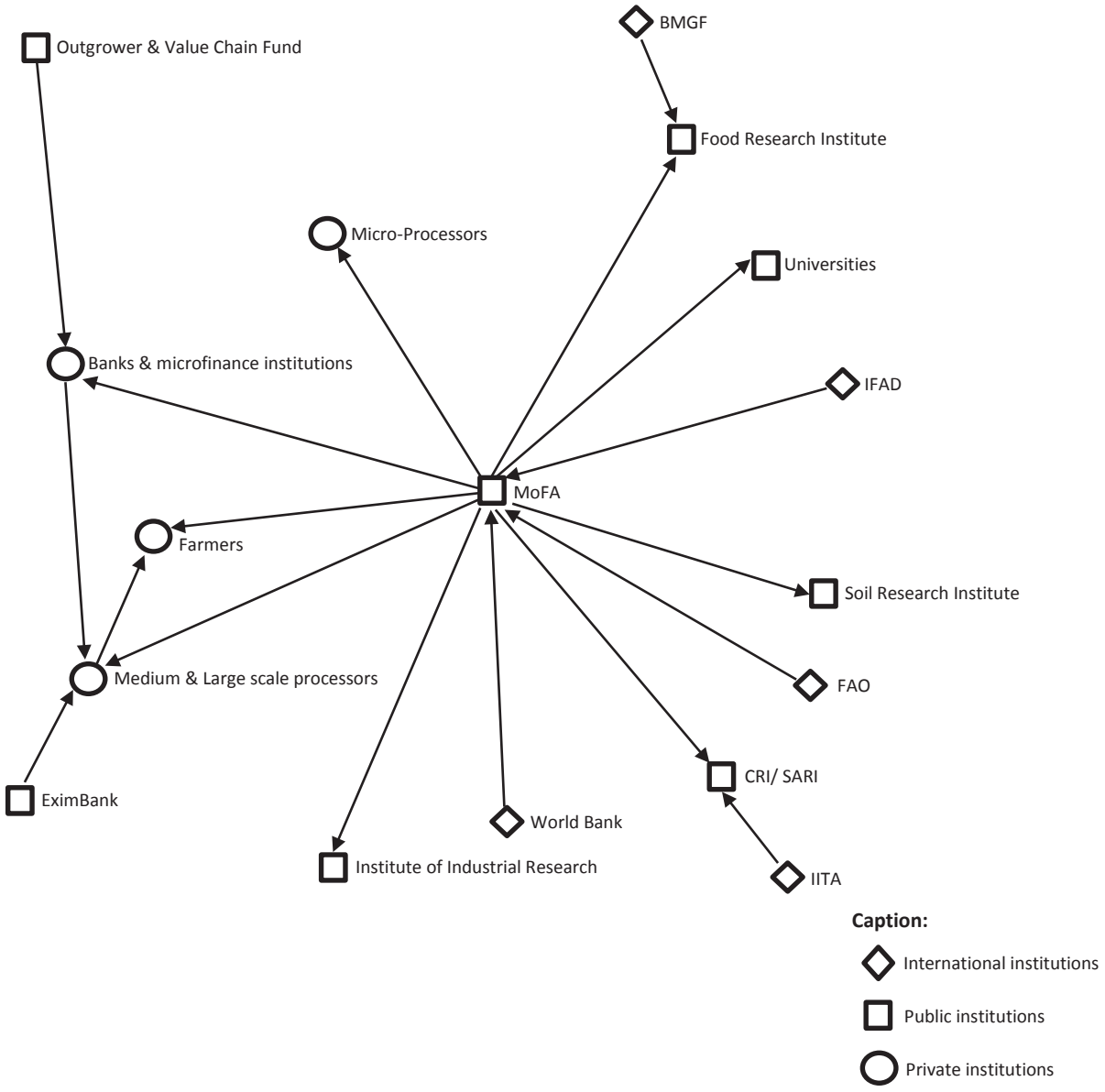


Fig. 3. Network of Fund flows.

other public and private sector actors. Conversely, private sector actors such as bakeries, plywood manufacturers and packaging companies share the least amount of knowledge with other actors. Indeed, fabricators do not transfer any knowledge in the network. IITA is also the only international institution that transfers and receives knowledge in the network.

5.3.3. Business linkages

The network for business linkages is dominated by private sector actors as expected (see Fig. 5). Medium and large scale processors are the most influential actor in controlling the flow of business in the cassava value web. Accordingly, medium and large scale processors have the most number of business linkages in the network, followed by farmers and micro-processors. These actors have the easiest access to other actors in establishing business collaborations. For instance, all industrial end-users deal directly with medium and large scale processors in the network.

Conversely, the only public sector actor in the network, GRATIS, has little influence in controlling the flow of business in the network. The structure of the network is reflected in the centrality measures of the business linkages (see Appendix 3).

5.4. Challenges and opportunities in the cassava value web

A summary of the main findings from the expert interviews on the challenges and opportunities in the cassava value web are presented in Table 4 using the Diamond model framework to categorise the themes.

5.4.1. Challenges

The expert interviews confirmed that a factor condition such as the predominance of subsistence-based smallholder cassava production in Ghana has meant minimal use of inputs and rudimentary agronomic practises in the cassava value web. This has contributed to relatively low yields. Respondents also pointed out the major challenge of poor road networks.

The interview information collected for this study as well as direct observation of various facilities suggests that in terms of

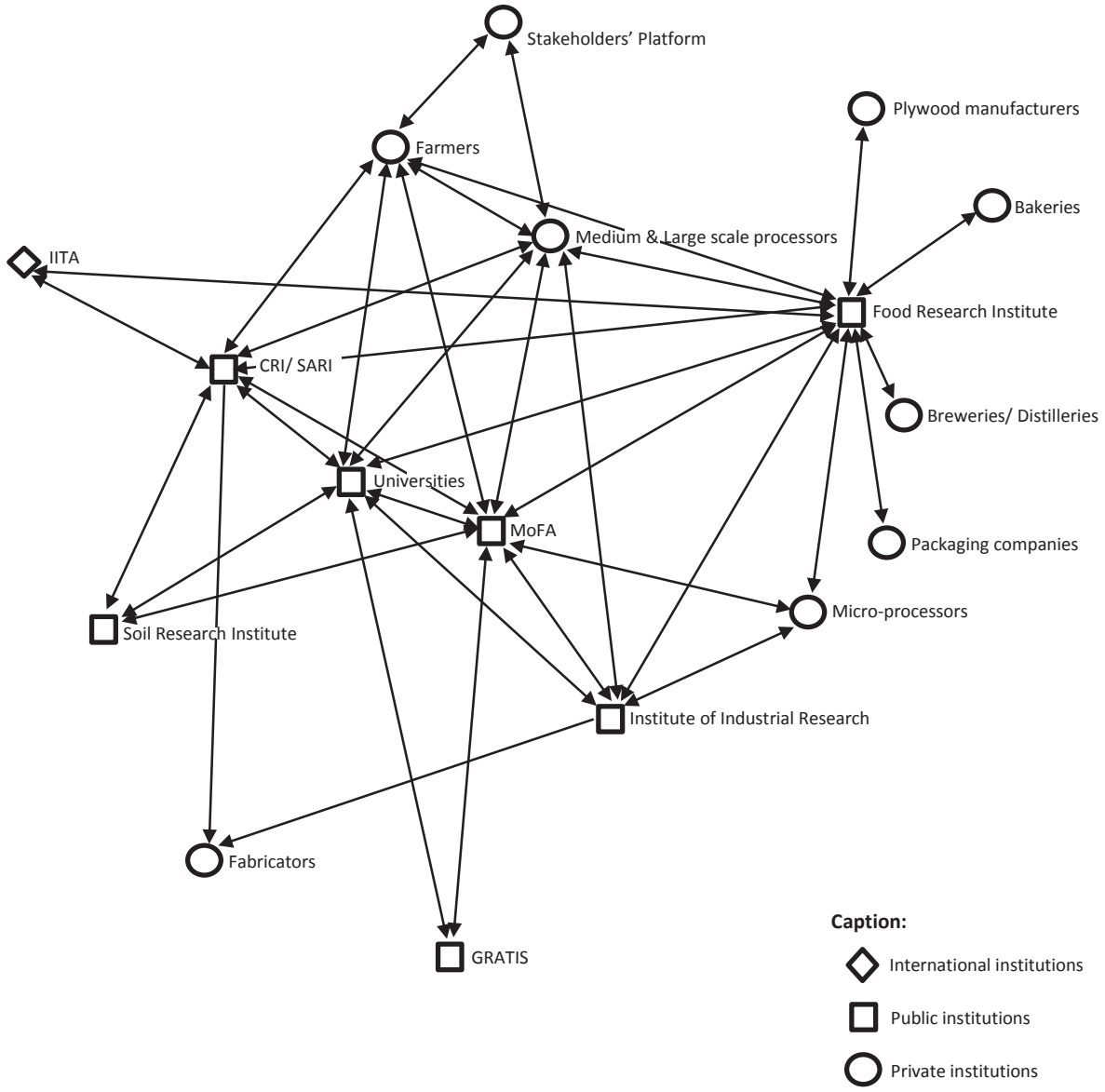


Fig. 4. Network of Knowledge flows.

demand conditions in the value web, processors tend to have inconsistent demand for cassava roots because they usually operate below installed capacity. According to interview information, this serves as a disincentive for farmers to increase yields or production volumes.

Respondents of the study observed that there is generally a lack of private sector initiatives in the development of new cassava based products in Ghana, with very few exceptions. Most processors and industrial end-users refrain from investing in the development of innovative ways of utilising the crop biomass.

Respondents emphasised that the public extension system, a supporting institution of the value web, is understaffed and under-resourced in its role of promoting new technologies among farmers.[1] This has contributed to low adoption rates of improved technologies among cassava farmers in Ghana. According to interview information, commercial banks and microfinance institutions also tend to be wary of agricultural investments given the high level of risk and unpredictability associated with such investments.

Respondents of the study pointed out that currently, Ghana does not have a cassava development policy. The government has however recognised cassava's economic potential by supporting several programs and projects as well as by way of the PSI on cassava starch introduced in 2001. Yet, these efforts have largely proved to be either unsustainable or unsuccessful in most cases. Beyond that, interview information also emphasised the lack of legislation in the form of a composite flour policy or a biofuel blend policy that would mandate the use of cassava based products such as HQCF or bio-ethanol.

5.4.2. Opportunities

Respondents pointed out that most parts of Ghana have the climatic conditions conducive for growing cassava. However, there is still a lot of unutilised farm land available for large scale commercial investments. Nonetheless, despite widespread subsistence cultivation, there is commonly significant surplus produce of

[1] The extension-farmer ratio in Ghana is currently 1:1500 (MoFA, 2015b).

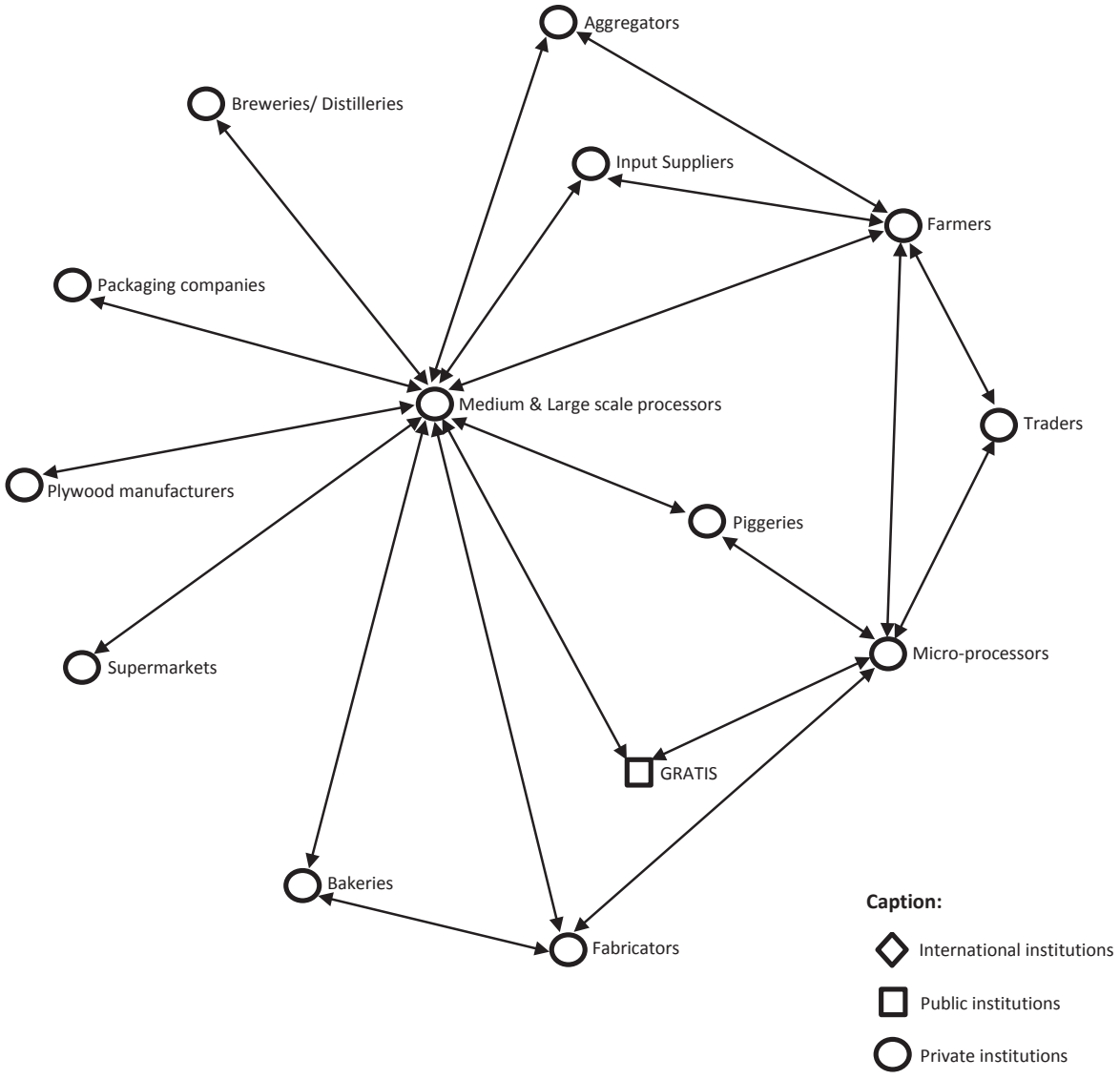


Fig. 5. Network of Business linkages.

cassava which is wasted or remains unharvested because farmers are unable to find off-takers. Respondents noted that there is therefore a huge potential for the industrial use of cassava in Ghana without food security being adversely affected.

According to the information collected for this study, there is growing domestic demand for cassava based products such as processed food products and alcoholic beverages. There is also rising demand across other countries in the West African sub-region. Consequently, the pharmaceutical, textile and food and beverage industries, among others, are becoming increasingly aware of the industrial applications of cassava.

The expert interviews confirmed that medium and large scale processors have started employing outgrower and contract farming models to help secure a reliable supply of cassava roots from farmers in adequate volumes. Another strategy being employed by processors is the diversification of their production portfolios. According to interview information as well as direct observation, most processors hedge their risk of making losses by producing more than one cassava product.

Respondents noted that public research institutions have been effective in supporting the growing cassava value web. CRI and SARI have bred twenty-four improved cassava varieties. The Food Research Institute has also been instrumental in the development and application of new products such as HQCF and industrial grade cassava flour in Ghana. Furthermore, respondents confirmed that local fabricators are becoming more proficient in manufacturing processing equipment.

Cassava has been earmarked as one of Ghana's food security crops in the government's sector-wide policy (FASDEP). Respondents observed that this has resulted in increased focus on research on improving cassava productivity. According to the expert interviews, another notable initiative by the government has been an excise duty concession for local content beers announced in 2012.[2] This tax incentive policy has encouraged the introduction of two cassava beers in Ghana. Respondents also noted that Ghana has a draft National Biofuel Policy which aims to accelerate the development and use of second-generation biofuels (using the non-edible parts of food crops) when enacted.

[2] This is a tiered reduction in excise tax for beers that contain more than 30% of locally sourced content.

Table 4
Matrix of themes from expert interviews.

Themes from Expert Interviews			Interview number							
			4	6	8	10	12	14	16	18
Challenges	Factor conditions	>90% subsistence-based smallholder cultivation								X
		Limited labour available for harvesting			X					
		Poor road networks								X
	Demand conditions	Inconsistent demand for cassava roots from processors						X		
		Reluctance of industrial end-users to use cassava products due to supply and quality concerns							X	
	Firm strategy, structure and rivalry	Lack of private initiatives in the development of new cassava based products				X				
		Dependence on imported inputs							X	
	Related and supporting industries	Weak public extension system to support farmers in adopting new technologies					X			
		High cost of credit and loan facilities from financial institutions								X
		Lack of continuous supply of electricity from the state		X						
	Government policies	Lack of a cassava development policy like for cocoa								X
		The unsustainability of projects and initiatives such as the PSI on cassava starch				X				
		Lack of a composite flour policy							X	
		Lack of a biofuel blend policy	X							
Opportunities	Factor conditions	Availability of land								X
		Good climatic conditions			X					
		Surplus cassava production in excess of subsistence needs				X				
	Demand conditions	Growing local and regional markets for cassava-based products					X			
		Latent demand for the industrial applications of cassava					X			
	Firm strategy, structure and rivalry	Outgrower/contract farming models for sourcing cassava								X
		Diversification in processing cassava based products				X				
		Recognition of the zero waste potential of cassava biomass			X					
	Related and supporting industries	Good research institutions involved in breeding and product development							**X**	
		Growing capacity in the manufacturing of processing equipment by local fabricators				X				
		Establishment of an industrial cassava stakeholders' platform		X						
	Government policies	Cassava a priority crop for food security (FASDEP)						X		
		Excise duty concession for local content beers		**X**						
		One-District-One-Factory Programme						X		
		Draft National Biofuel policy	X							

6. Discussion

This study aimed to identify the potential of Ghana's cassava value web in contributing to the emerging bioeconomy. From the application of the Diamond Model, it is evident that despite opportunities to develop a competitive value web, critical challenges remain. Deficiencies in the institutional linkages between actors and a less than conducive policy environment appear to be hampering innovation and development of the value web. The reasons are discussed in the following sub-sections.

6.1. Underdeveloped factor conditions

Cassava cultivation is dominated by small scale subsistence-based farmers in Ghana. At that scale, farmers make use of limited chemical and technical inputs in the production, harvesting and post-harvest handling of the crop. The findings of the study indicate that there are deficiencies in the institutional linkages (funding, knowledge and business interactions) within the cassava sub-sector. This leads farmers to believe that there is insufficient demand for their produce, even when demand exists among certain processors. A major contributing factor to this problem has been poor road infrastructure which causes inaccessibility and raises the logistical costs of processors acquiring and transporting cassava from widely dispersed smallholders. These conditions in turn serve as a disincentive for farmers to increase their planted area or adopt new technology and agronomic practices to increase their productivity. This is consistent with the findings of Acheampong et al. (2017) and Onumah et al. (2008) that marketing challenges contributed to the reluctance of smallholders in Ghana to increase their cassava production.

6.2. Deficient demand conditions

The study's findings indicate that medium and large scale processors are very often faced with the challenge of securing sufficient volumes of fresh cassava when demand arises. This is due to low farm productivity and lack of accessibility. Thus, most processors are forced to operate below installed capacity. Similarly, Kleih et al. (2013) found that since the Ayensu Starch factory was established in 2002 under the PSI, it has never operated at full capacity mainly due to insufficient supply of cassava roots. This affects the quantity of cassava products like starch or flour that are processed to meet the demand of end-users. As shown in the network of business linkages (Fig. 5), medium and large scale processors are the main source of cassava products for various end-users. Inconsistent supply of these cassava products has created reluctance among industrial end-users to replace their current inputs. Many processors are also unable to meet the quality standards of industrial end-users, leading to rejections. Thus, high rejection rates and low confidence in processors' ability to supply the required volumes has led to low demand for cassava products by industrial end-users. As a result, a vicious cycle is created because processors in turn do not have sufficient demand to consistently buy cassava from farmers.

6.3. Lack of innovative firm strategy, structure and rivalry

Potential end-users of cassava products such as the pharmaceutical and textile industries in Ghana appear to lack initiative in developing cassava products suitable for their production processes. Locally produced medical-grade starch and ethanol for instance could replace imports of these products for pharmaceutical companies. The results of the study indicate that this is a task that has

been left to public research institutions which are solely dependent on donor funds as evidenced by the networks of knowledge and fund flows (Figs. 3 and 4). The Food Research Institute, for example, has been instrumental in the development and application of HQCF, a major intermediate product, in Ghana (see Dziedzoave et al., 2006; Dziedzoave et al., 2003). In some industries, there is still a low level of awareness of the potential of cassava products to substitute imported goods. However in industries where there is awareness, most end-users are unwilling to commit resources to develop the needed supply chain in terms of ensuring that requirements of supply volumes, quality standards and competitive pricing are met. There might also be additional costs associated with switching inputs such as installing new equipment. Moreover, it must be noted that cassava products are not always cheap enough to warrant producers switching from imported alternatives. Koyama et al. (2015) found that biscuit companies in Ghana rely on wheat flour imports from Turkey which is cheaper than HQCF. Abass et al. (2011) reported a similar situation in Nigeria.

6.4. Inaccessible related and supporting industries

The primary crop breeding institutions in Ghana, CRI and SARI, as well as the public universities have been effective in developing improved cassava cultivars. However, uptake among farmers has remained relatively low. Alene et al. (2015) found that the area planted to improved cassava varieties in Ghana only increased from 25% in 1998 to 36% in 2009. The study found that the limited number of agricultural extension agents to promote these technologies has been a contributing factor to the low adoption rate. The poor coverage and low extension-farmer ratio have primarily been caused by staff attrition and a lack of replacements and recruitments by MoFA. This is in line with a freeze on public sector hiring in an attempt to reduce the government wage bill.

Access to formal sources of financing for farmers and processors also remains a critical challenge in Ghana as confirmed by studies by Acheampong et al. (2017) and Essegbey (2009). Banks and microfinance institutions offer high interest rates of between 18 and 25% per year for loans and credit facilities, making them inaccessible to most enterprises. The network analysis confirms the weak interaction between financial institutions and the cassava sub-sector. For instance, Fig. 3 shows that banks and microfinance institutions do not have direct interaction with farmers and microprocessors. Similarly, medium and large scale processors tend to struggle to compete with the price of imported goods due to these high costs of finance. Available value addition technologies are also underutilised by processors because of financial constraints. Furthermore, persistent challenges with state supplied electricity have compelled processors to invest in alternative sources of power generation like generators to stay in business. This has led to higher operating costs and a significant downturn in operations.

These institutional challenges have inhibited the role these supporting institutions are supposed to play in facilitating much needed investments in 'factor upgrading' in cassava production and processing in Ghana.

6.5. Missing government policies

Cassava does not have a specific sub-sectorial policy like cocoa (see Poku, 2017). This invariably means government support tends to focus on specific aspects of the sub-sector rather than taking a more holistic approach. The study confirms that government policies supporting the development of the cassava sub-sector in Ghana thus far have mainly focused on improving productivity and food security. There has been less emphasis on commercialisation and industrial development. This is evidenced by the study's finding of the lack of a direct institutional linkage between government agencies and industrial end-users (Figs. 4 and 5). Koyama et al. (2015) point out that based on the success of Thailand and Vietnam, African countries must recognise the important role of government policies in stimulating demand and sustained market opportunities both locally and internationally for high value cassava products. Correspondingly, the study's findings indicate that unsuccessful initiatives such as the PSI on cassava starch and the absence of legislation such as a composite flour policy or a biofuel blend policy have been major contributing factors to the unrealised industrial potential of cassava in Ghana thus far. In this regard, companies with strong political connections might also have entrenched interests in maintaining the status quo of a system fully dependent on certain imports.

Overall, the study's findings show that a conducive policy and institutional environment are critical to realising the untapped potential of cassava and developing a competitive value web in Ghana.

7. Conclusions

In this paper, the policy and institutional environment required for developing a competitive and sustainable bioeconomy in Africa were analysed using the novel concept of biomass-based value webs. Cassava in Ghana was used for an empirical case study. The analysis, which was based on a combination of social network analysis and content analysis of expert interviews, revealed the challenges and opportunities of developing a competitive cassava value web in Ghana.

The findings indicate that overcoming the challenges of low farm productivity, low utilisation of cassava biomass by processors and low demand by industrial end-users hinges on improved coordination between value web actors. Outgrower or contract farming models can serve as an effective means of strengthening these institutional linkages. Supporting institutions such as financial institutions and public extension services also have critical roles to play in strengthening fund flows, knowledge transfer and business linkages between actors. Furthermore, government policies that actively support the use of local content across industries would incentivise end-users to adopt cassava products and thus give processors the assurance of a ready market for their products. This will incentivise increased farm productivity.

The study concludes that there are important complementary roles that need to be played by a diverse set of institutions within an enabling environment in order to realise competitive biomass production and utilisation in Africa's emerging bioeconomy.

Declarations of interest

None.

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Appendix

Appendix 1
Centrality measures of Fund flows

	(Out)Degree Centrality	(In)Degree Centrality	(Out)Closeness Centrality	(In)Closeness Centrality	Betweenness Centrality
World Bank	1	0	0.31	0.25	0
IITA	1	0	0.26	0.25	0
FAO	1	0	0.31	0.25	0
BMGF	1	0	0.26	0.25	0
IFAD	1	0	0.31	0.25	0
Institute of Industrial Research	0	1	0.25	0.27	0
Food Research Institute	0	2	0.25	0.28	0
Aggregators	0	0	–	–	0
GRATIS	0	0	–	–	0
Input Suppliers	0	0	–	–	0
Soil Research Institute	0	1	0.25	0.27	0
CRI/SARI	0	2	0.25	0.28	0
Ministry of Food & Agriculture	9	3	0.33	0.27	27
Farmers	0	2	0.25	0.30	0
Fabricators	0	0	–	–	0
Banks & microfinance institutions	2	2	0.27	0.28	3
Micro-processors	0	2	0.25	0.29	0
Universities	0	1	0.25	0.27	0
Stakeholders' platform	0	0	–	–	0
Outgrower & Value Chain Fund	1	0	0.27	0.25	0
EximBank	1	0	0.26	0.25	0
Medium & Large scale processors	1	3	0.26	0.30	3
Bakeries	0	0	–	–	0
Piggeries	0	0	–	–	0
Supermarkets	0	0	–	–	0
Breweries/Distilleries	0	0	–	–	0
Plywood manufacturers	0	0	–	–	0
Packaging companies	0	0	–	–	0
Traders	0	0	–	–	0

Appendix 2
Centrality measures of Knowledge flows

	(Out)Degree Centrality	(In)Degree Centrality	(Out)Closeness Centrality	(In)Closeness Centrality	Betweenness Centrality
World Bank	0	0	–	–	0
IITA	2	2	0.35	0.34	0
FAO	0	0	–	–	0
BMGF	0	0	–	–	0
IFAD	0	0	–	–	0
Institute of Industrial Research	6	5	0.38	0.36	7.57
Food Research Institute	12	12	0.41	0.40	119.13
Aggregators	0	0	–	–	0
GRATIS	2	2	0.33	0.33	0
Input Suppliers	0	0	–	–	0
Soil Research Institute	3	3	0.34	0.33	0
CRI/SARI	8	7	0.39	0.37	21.50
Ministry of Food & Agriculture	9	9	0.39	0.38	27.97
Farmers	6	6	0.38	0.37	12.13
Fabricators	0	2	0.25	0.33	0
Banks & microfinance institutions	0	0	–	–	0
Micro-processors	3	3	0.36	0.35	0
Universities	8	8	0.39	0.38	19.83
Stakeholders' platform	2	2	0.32	0.32	0
Outgrower & Value Chain Fund	0	0	–	–	0
EximBank	0	0	–	–	0
Medium & Large scale processors	7	7	0.38	0.37	15.87
Bakeries	1	1	0.34	0.33	0
Piggeries	0	0	–	–	0
Supermarkets	0	0	–	–	0
Breweries/Distilleries	1	1	0.34	0.33	0
Plywood manufacturers	1	1	0.34	0.33	0
Packaging companies	1	1	0.34	0.33	0
Traders	0	0	–	–	0

Appendix 3
Centrality measures of Business linkages

	(Out)Degree Centrality	(In)Degree Centrality	(Out)Closeness Centrality	(In)Closeness Centrality	Betweenness Centrality
World Bank	0	0	–	–	0
IITA	0	0	–	–	0
FAO	0	0	–	–	0
BMGF	0	0	–	–	0
IFAD	0	0	–	–	0
Institute of Industrial Research	0	0	–	–	0
Food Research Institute	0	0	–	–	0
Aggregators	2	2	0.33	0.33	0
GRATIS	2	2	0.33	0.33	1.25
Input Suppliers	2	2	0.33	0.33	0
Soil Research Institute	0	0	–	–	0
CRI/SARI	0	0	–	–	0
Ministry of Food & Agriculture	0	0	–	–	0
Farmers	5	5	0.35	0.35	11.25
Fabricators	3	3	0.34	0.34	2.75
Banks & microfinance institutions	0	0	–	–	0
Micro-processors	5	5	0.33	0.33	6.5
Universities	0	0	–	–	0
Stakeholders' platform	0	0	–	–	0
Outgrower & Value Chain Fund	0	0	–	–	0
EximBank	0	0	–	–	0
Medium & Large scale processors	11	11	0.37	0.37	57
Bakeries	2	2	0.33	0.33	0
Piggeries	2	2	0.33	0.33	1.25
Supermarkets	1	1	0.32	0.32	0
Breweries/Distilleries	1	1	0.32	0.32	0
Plywood manufacturers	1	1	0.32	0.32	0
Packaging companies	1	1	0.32	0.32	0
Traders	2	2	0.32	0.32	0

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