Towards Resilient Agricultural Development: Bottlenecks to the Adoption of Bioeconomy in sub-Saharan Africa

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Abstract

In light of the challenges posed by climate change and population growth, agro-industry in sub-Saharan Africa (SSA) is under pressure for more efficient and sustainable use of natural resources. Bioeconomy has been promoted as promising and effective model for sustainable development in low-income countries. Nevertheless, there is persistent risk that bottlenecks along the value chain of bioeconomic adaptation could have a negative impact on local actors. With the aim to shed light on possible patterns in those bottlenecks and to create an information base for adaptation measures, this study analyzes interviews with multiple experts connected to the field. Our findings imply that bioeconomic models need to be designed and implemented in a context-specific manner throughout the whole value chain. Potential bottlenecks for agro-industry in SSA have been identified in the social, technological, economic, legislative and educational dimension, as well as financial. Moreover, in order to be successfully implemented, bioeconomy needs to respond to the pressing issues faced by sub-Saharan Africa. Bearing in mind that the next few decades will be decisive in shaping and implementing a new and transformative global agenda, the successful establishment of bioeconomy could in all probability increase the resilience of SSA societies to global socioeconomic and environmental challenges.

Contents

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1 Introduction

People and population dynamics are at the core of sustainable development. The latest United Nations population projections (2019) indicate an immense increase in the global population level: world population is expected to reach 9.7 billion in 2050. Those projection signal that sub-Saharan Africa (SSA) will account for more than half of world's population growth between 2019 and 2050. At the same time, Africa has been identified as one of the areas most vulnerable to the impacts of climate change (Serdeczny et al., 2017). The challenges deriving from these forecasts will manifest in different ways, for instance southern African territories are projected to experience a high risk of droughts, whereas East Africa will be more affected by flooding.

The agricultural sector, employing more than half of the total workforce in SSA, will also be strongly affected by the interaction of demographic and climate change related issues (OECD/FAO, 2016). Given its role in confronting the challenge of eradicating hunger and improving food security, the agricultural sector has a pivotal responsibility in the management of natural resources. It is clear that the need for sustainable solutions for efficient natural resource management is urgent. In this framework, bioeconomies are promoted as promising and effective model for sustainable growth in both developed and developing countries (Ingrao et al., 2018).

Bioeconomy at large involves the implementation of advances in biological sciences into industrial processes. Moreover, bioeconomy is based on biological resources, namely materials of biological origin, and is an umbrella term which includes food, feed, biofuels and the related bioenergy and bio-based products. While many countries have already designed bioeconomic strategies or policies at a national level, Africa and specifically sub-Saharan Africa do not present the same diffusion as other continents (Figure 1). Specifically in SSA, the risk of exacerbating the conflict between food and non-food production (for instance the "food versus fuel" debate) remains severe, thus the need for circularity and sustainable natural resource management. It has to be noted that bioeconomy does not inherently entail the concept of sustainability (Issa et. al., 2019; Pfau et al., 2014), making it largely dependent on the mode of implementation. Thus, the

risk of a shallow realization would be ultimately threatening food security in areas which are already vulnerable.

Figure 1. Bioeconomy policies and strategies established by 2017 (BÖR 2017).

From an economic point of view, bioeconomy could foster sustainability through value addition applied to biomass and the creation of new jobs, especially impactful on women and rural youth. Moreover, the creation of stronger rural-urban links and local value chains has the potential to improve economic resilience (Gomez San Juan et al., 2019).

While the prospective benefits of bioeconomy have been fairly investigated and recognized (Global Bioeconomy Summit, 2015), the bottlenecks to its implementation along the value chain are far less acknowledged.

Bioeconomy is, by nature, both global and local. Both aspects need to be addressed, although the local adoption, which requires the design of tailored solutions for each context, turned out to be particularly difficult to assess. Bioeconomy at such a level cannot and should not be developed detached from the concurring circumstances. At the same time, devising a global approach for successful adoption of bioeconomy in heterogeneous environments has proved challenging.

This paper builds on the hypothesis that patterns in bottlenecks to the implementation of bioeconomy can be identified and collected to form an information base. The result is intended as a tool to better design effective bioeconomic measures and assist in their implementation, especially in SSA, in terms of adaptation to future challenges. In this framework, the aim of this work is to collect expert opinions on the bottlenecks that may arise at various levels (as design, production and end-of-life) of the bio-economic value chain.

Sustainable production achieved through the maintenance of natural resources is the primary objective of bioeconomy. This refers to the enhancement of food security and improved development while having the potential to impact multiple Sustainable Development Goals (SDGs) at once. In figure 2, SDGS which are most directly influenced by bioeconomy activities are summarised. Since the research focuses on bioeconomy applied to the agro-industry, No Poverty (SDG 1), Zero Hunger (SDG 2), Good Health and Well-Being (SDG 3), Climate Action (SDG 13) and Life on Land (SDG 15) are particularly relevant.

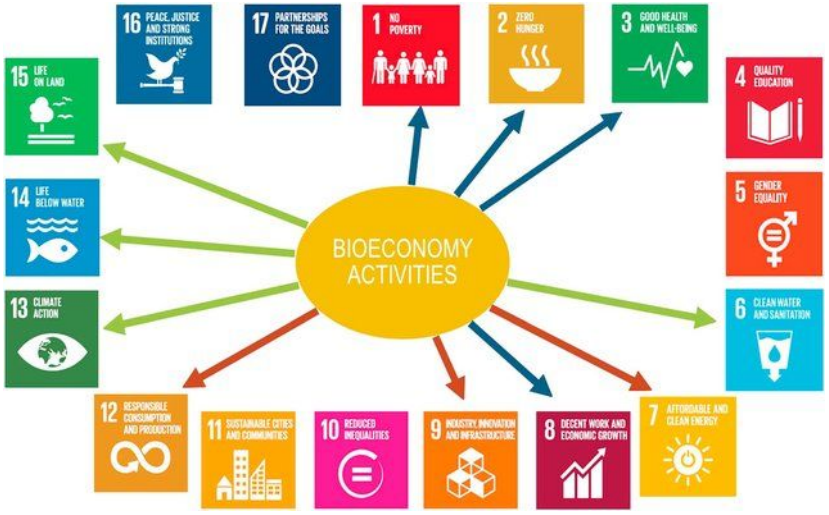

Figure 2. Bioeconomy relations to the Sustainable Development goals (Heimann, 2018).

The remainder of this paper is structured as follows: Section 2 provides a brief overview of the theoretical literature on agri-food chain sustainability and bioeconomy. Furthermore, this section sheds light on the development aspect of bioeconomies and the occurring of possible bottlenecks. The following section presents the research design and strategy. In section 4 the results that have been obtained during expert-interviews are presented, whereas section 5 provides a detailed analysis of our findings. In the final section, recommendations based on the findings of this study are outlined.

In view of the above, this research project can yield valuable insights to governmental and non-governmental organisations (such as the United Nations) working on implementation of bioeconomy in SSA.

2 Theoretical Framework

Bioeconomy is defined as "the production, utilization and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes and services across all economic sectors aiming toward a sustainable

economy" (Global Bioeconomy Summit, 2018). It is therefore evident that bioeconomy could positively impact agri-food chain and generate added value and additional income, if correctly implemented.

While originally bio-based economy was encouraged in order to substitute the rapidly depleting fossil fuels reserves and in the light of economic concerns about rising prices, today the paradigm has shifted to the reduction of greenhouse gases emission and towards a more sustainable economic system (Birner, 2018). Bugge and colleagues (2016) argue that bioeconomy as a concept is still rather fragmented, with different meanings according to the field where it is investigated or implemented in. Nevertheless, three different visions of bioeconomy can be identified in the literature: a biotechnological vision, focusing on research, application and commercialization of biotechnology, a bioresource vision, centered around the processing and upgrade of biological raw materials and the establishment of new value chains, and a bio-ecology vision, which concentrates holistically on the concept of ecosystem services and biodiversity conservation.
In terms of global discourse, biodiversity is declined differently according to the operational field of the different actors which apply it. Institution-wise, specifically referring to the way bioeconomy is addressed by UNIDO (2017), it appears clear that the vision promoted by the organization represents a blend of the first two approaches, while FAO (2019a) refers mostly to the last two, which relates to the spheres of interest of the different agencies.
Lastly, an extensive analysis of the narrative on bioeconomy has been conducted by Vivien and colleagues (2019) who further attribute the vision expressed by the Organization for Economic Co-operation and Development (OECD) to what they named science-based bioeconomic approach, driven by industrial biotechnology, while the European Commision vision is being traced back to a "biomass-based bioeconomy", namely a bioeconomic approach which attempts to transform biomass from various sources.

2.1 Agri-food Chains Sustainability and Bioeconomy

Sustainable supply chains are to be viewed as "management of raw materials and services from suppliers to manufacturer/ service provider to customer and back with improvement of the social and environmental impacts explicitly considered" (NZBCSD, 2003). This means that the potential benefits derived from the sustainable supply chain management need to be extended as far upstream and downstream as possible. In order to holistically address this issue, the supply chain must be designed appropriately as proposed by Iakovou and colleagues (2014). The researchers suggest that the design of an holistic green agro-industrial supply chain (Figure 3) needs to take the following aspects into consideration:

I. sustainable farming: preservation of ecosystems, sustainable management of land, water and natural resources while ensuring food security and social and economic equity (as defined by FAO).

II. environmental management: reduction of energy use, reduction of inputs, emission reduction and control and climate change adaptive management.
III. reverse logistics: sustainable restoration of inputs and materials, waste management and packaging reuse.
IV. supply chain management: sector-specific strategies which take into account the unique characteristics of agro-industries (for instance perishability of goods).
V. marketing: pricing, consumer satisfaction and knowledge.
VI. corporate/social responsibility: commitment to sustainability as a whole, mitigation of irresponsible behavior and mitigation of resource waste.

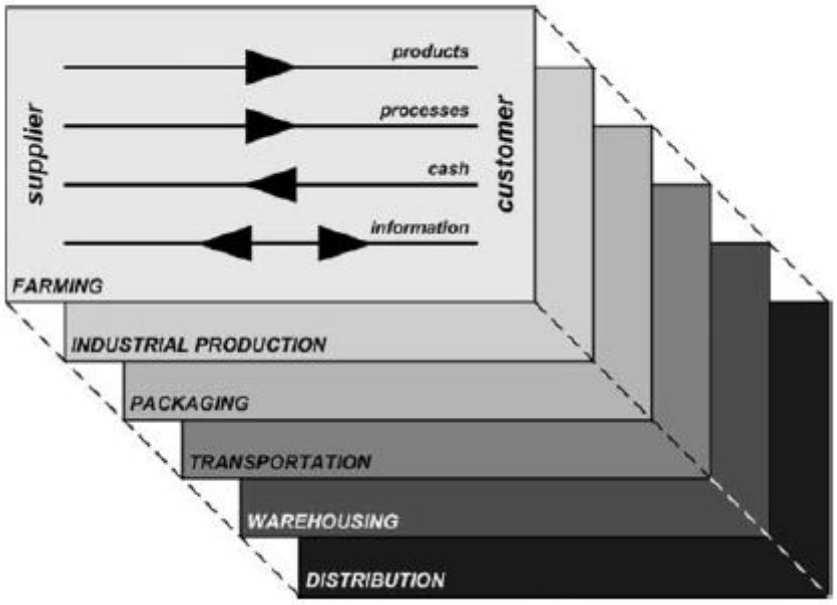

Figure 3. Agro-industry supply chain echelons (Iakovou et al.,2014).

Worldwide, the agri-food chain presents inherent weaknesses that could be addressed through designs that incorporate sustainability. Considering the agri-food chain in low income countries, specifically, producers are exposed to multiple risks, such as natural disasters, erratic prices, diseases, conflicts and restricted resource and market access (European Commission, 2019). Especially considering the intensity of potential natural disasters and the destruction of critical agricultural assets and infrastructure, long-lasting adverse impacts on the activities of the agricultural value chain become most evident (FAO, 2017). In order to address the weak points along the agri-food chain, adding value to the agricultural production, for instance through the means of processing industries, could offer potential. This would apply especially to boosting rural employment, incomes, reducing poverty and improving nutrition. In particular, the promotion of agro-industries, especially small and medium, has been proved to be an effective measure to foster the development of rural populations. Conversely, agriculture, and therefore agri-food chains, poses a threat to environmental stability. Indeed, agriculture has been identified as a major driver of four out of five high risk or increasing risk zone planetary boundaries

(Figure 4): biosphere integrity, land system change, freshwater use, biogeochemical flows and climate change (Campbell et al., 2017).

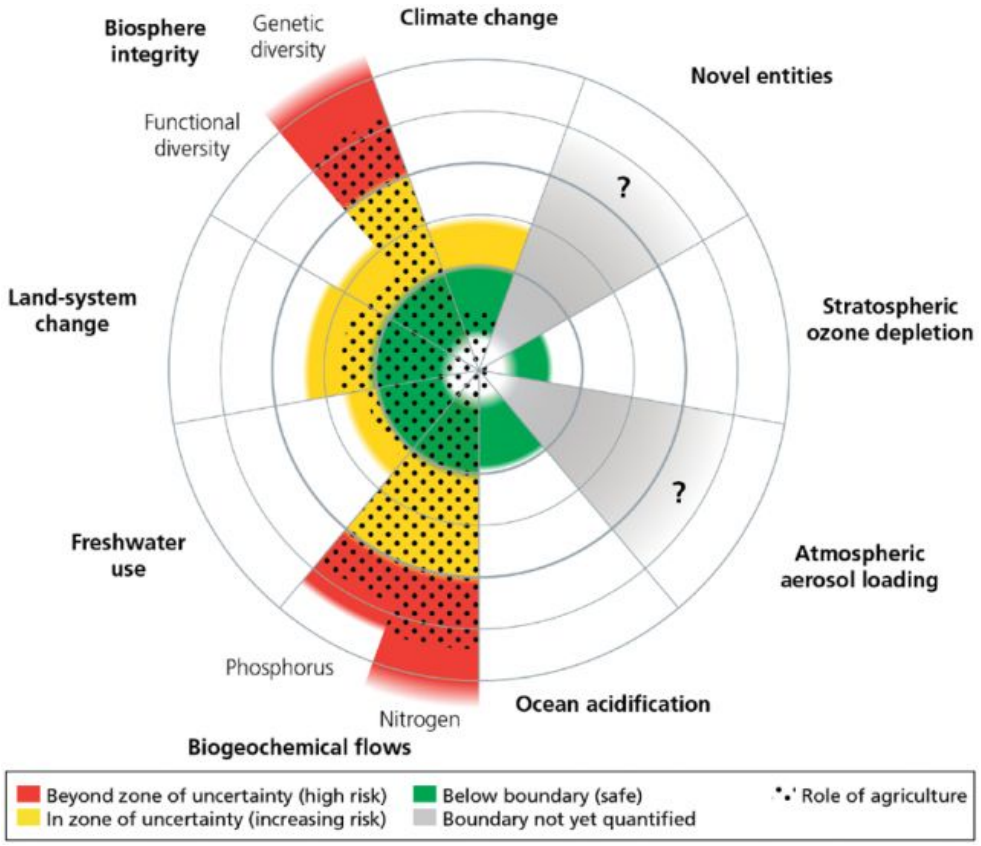

Figure 4. The contribution of agriculture to the status of planetary boundaries. The boundary itself lies at the intersection of the green and yellow zones (Campbell et al. 2017).

Within this context, the enhancement of resilience is of particular interest. It is crucial that resilience is applied not only to production but to all aspects of the value chain, in order to guarantee the "long-term survival of working agricultural landscapes" (Vroegindewey and Hodbod, 2018).

At present, agro-industry is characterised by immense transformations at the macro- and micro-level. Those are driven by demographic dynamics, globalisation, growing food demands and environmental pressure (Vroegindewey and Hodbod, 2018). Being able to address these changes involves elaborating concepts beyond conventional supply chain analysis. In this sense, value chains represent a more holistic framework, providing a more in-depth understanding of the chain structure and the role of the respective actors.

Value chains are "the set of sequenced value-creation activities that convert raw materials to final products, and the institutions that link these different production nodes" (Vroegindewey and Hodbod, 2018). They represent the junction between agro-ecological systems, households, and markets, and are therefore pivotal to the social structure of food systems (Eriksen, 2008),

particularly relevant in low income countries. Their role is related to three main aspects: the provision of stable access to markets (Barrett et al., 2010), the availability of diverse and nutritious foods, even in presence of unpredictable shocks (Tendall et al., 2015) and, lastly, the cost-effectiveness related to the presence of established value chains (Irwin and Campbell, 2015).

The efficiency and success of value chains is strongly dependent on the maintenance of natural resources and their access. This, in turn, positions planetary boundaries, and maintaining a "safe operating space" for humanity within them, as a pivotal concept.
Consequently, this approach is in line with the increasing urgency to adopt climate-change-mitigating and adapting-measures and with the necessity to avoid crossing the planetary boundaries (Rockstroem et al., 2009; Steffen et al., 2016).

2.2 Bioeconomy and Development

According to CGIAR (2013), agricultural research in general, and even more so the one conducted in low income countries, has as an ultimate goal to improve food security, nutrition and health, while reducing rural poverty and enhancing the sustainable management of natural resources. The majority of low income households depends on agricultural produce for both their income and food supplies. This translates into a higher benefit to the global poor population when the agricultural sectors grow: agri-food output is crucial for achieving poverty reduction (Wiggins, 2005).
While value chain is already regarded as a key concept in developing sustainable food systems and as a fundamental paradigm in development in general, bioeconomy has just started to impose itself as a viable development solution (FAO, 2014). It must be noted that bioeconomy is not inherently sustainable. While it is usually implemented expecting economic development, often in the shape of additional income opportunities in rural areas, and ecological benefits, such as climate change mitigation, care is required in implementing bioeconomic strategies. In a scenario where competition for land is already expected to increase due to the rise in world population, bioeconomy risks to exacerbate the issue if not managed correctly.

From an economic point of view, sustainable development has been operationalized based on capital theory approach (Atkinson, 2008 and Stern, 1997; as cited in Gaitán Cremaschi, 2016). This comprises three main types of capital, after the dimensions of sustainability:

I. natural capital: renewable and non-renewable natural resources;
II. human capital: education, skills, culture and knowledge;
III. man-made capital: buildings, tools, and other physical assets, thus, all produced goods (Ruta and Hamilton, 2007; as cited in Gaitán Cremaschi, 2016).

Two diverging theories deal with the appropriateness of the interchangeability between these three components: weak sustainability and strong sustainability. Weak sustainability is based on

the assumption that "man-made capital can replace any component of the natural capital and social capital" (Gaitán Cremaschi, 2016). Conversely, hard sustainability builds on the assumption that natural capital comprises *critical* components (such as water) that "provide irreplaceable life-support functions for humans as well for the resilience of ecological systems and thus, cannot be substituted" (Barbier et al., 1994; Ekins et al., 2003; van der Bergh, 2007; as cited in Gaitán Cremaschi, 2016). Therefore, this perspective suggests that the long-term maintenance of each individual component is critical to ensure sustainability in development (Costanza and Daly 1992; as cited in Gaitán Cremaschi, 2016). The same reasoning can be applied to the agri-food supply chain (Figge and Hahn 2004; as cited in Gaitán Cremaschi, 2016). In the framework of weak sustainability, an agri-food supply chain could be considered sustainable if the overall final performance was good. This implies that the good performance of one component could make up for any other low performing one. On the other hand, strong sustainability would require a minimum performance to be achieved at every stage of the supply chain and for every component (Gaitán Cremaschi, 2016).

In conclusion, particular importance must be placed on analysing aspects belonging to as many different stages as possible of both supply and value chains while evaluating their efficacy and their appropriateness, in achieving sustainability.

2.2.1 Risks and Chances

Bioeconomy is, despite constant efforts, still not well understood nor optimized, due to the vastity of its implications (Lewandowski, 2015). For instance, while bioeconomy carries the potential to address natural resources scarcity, it also entails the risk that the increased demand for biomass will put pressure on limited resources like water and phosphorus. Recommendations for development in this sector require a preliminary assessment that is trying to realize how the potential impact of certain bioeconomic developments and activities will work out. This is of special interest since it is seen as a major goal of bioeconomy to sustain food production and food security (Lewandowski, 2015).

At the same time, the debate on whether exiting poverty is pushed by the effects of sustainable agribusiness and food value chains and their respective impact on wages and enterprise development or simply by economic growth is still open. Nevertheless, examining the perception of FAO (2019a), the improvement of sustainable food value chains could potentially strengthen millions of poor households in developing countries while at the same time providing nutritious food for everyone.

2.2.2 Recommendations for Better Efficiency

UNIDO (2009) recommends to encourage smaller farmers and enterprises for agri-food development and poverty reduction. Their research shows that in some countries in Africa agricultural growth, which relies on smaller farms, has a high efficiency towards poverty reduction and generally shows bigger effects than in unequally distributed landholdings.

For a good bioeconomic development, which Lewandowski (2015) suggests for securing sustainable biomass supply in a growing bioeconomy, various experts from relevant disciplines such as agro-economists, social scientists, ecologists should work together. Furthermore the author is encouraging the discourse not to be limited to the scientific community but also to include various stakeholders, in order to fully understand the drivers and barriers that are of social and cultural origins. Moreover, at a broader level, Issa and colleagues (2019) argue that knowledge sharing among different nations is an important contributor to bioeconomic development across the world, especially for less developed countries, in order to build a global bioeconomy.

Technical capacities represent another crucial aspect in value chain design and implementation, due to intense competition and increasingly rapid industrial changes. Moreover, technical capacities are to be considered during the evaluation of the performance of production systems and tools: this information has, in turn, the potential to help to upgrade and enhance the competitiveness of producers (UNIDO, 2009).

Ertz and Sarigöllü (2019) recently assessed the potential of sustainable value chains in the collaborative economy and identified that regulation and governance should be considered as crucial elements of the value chain. Furthermore, they state that research that ensures the acquisitive, environmental and social effectiveness simultaneously needs to be tackled by all actors in the value chain.

Equally crucial to the selection and prioritization of value chains is understanding whether basic measures are met for the participation of markets in developing countries. In case these are not yet implemented, a development programme, including additional components to support value chain promotion projects, should be included. Lastly, when selecting value chains, business environments and policy frameworks need to be taken into consideration (UNIDO, 2009).

2.3 Evaluation of the Value Chain and Bottlenecks

As already outlined, bioeconomy adoption in agro-industry plays a central role in terms of development. Thus, policy makers and scholars have recently been focusing on this nexus. When it comes to developing countries, national funds have been primarily invested in agricultural production inputs. Formerly, the value chains by which final products reach consumers and the potential of such chains to generate added value and employment opportunities had not been on the agenda for quite a long time (UNIDO, 2009). Indeed, value chain participation has the potential to help Africa to develop, however trade-offs and synergies have to be considered . Dihel and colleagues (2018) refer to trade-offs in industrialisation that can arise in the shift of former activities which already possess existing comparative advantage to other ones. In industrial development, value chains help facing circumstances related to competitive deficits and development bottlenecks, simultaneously distributed at various levels of the value chain. Thus, it

is of utmost importance to map, evaluate and analyse those value-chains in terms of their potential bottlenecks.

Such analysis tools have already been captured from all sides - scholars, policymaker and international organisations make use of diverse techniques to evaluate such processes. However, existing approaches are not particularly specific to industrial value chains in developing countries (Hartwich et al., 2009).

Although bottlenecks in relation with the three dimensions of sustainability can be found, they often address only one specific aspect and thus only partially represent the inherent complexity of the value chain. As an example, Beuchelt and colleagues (2013) refer to the risk of upholding or even increasing social and gender inequalities. Indeed, different social groups share trade-offs or benefits in different ways - thus, what appears as progress for some, can bring negative side effects for others. In this sense, some guidelines have already been issued in order to address this complexity, specifically in terms of gender disparity (FAO, 2016). In terms of inequality, Diakosavvas and colleagues (2019) confirm that potential conflicts can arise between sustainability objectives to increase food security (SDG 2) and other demands in connection to natural resources. In addition, FAO (2013) identified weaker market institutions and the issue of inefficient governance caused by restrictive policies hindering development as a bottleneck. Furthermore, they highlight that coordination and collaboration on policy development and legislation are fundamental for sustainable agribusinesses and value chains. Lastly, regarding risks specific to low income countries, the high degree of corruption that can be found there represents a major bottleneck (Olken and Pande, 2012). As regards potential bottlenecks relative to bioeconomy, the concept of the reduction of greenhouse gas emissions accomplished through it is met with several concerns in relation to savings from feedstock production as well as the changes in land-use and fuel versus food competition. With the implementation of bioeconomy, new challenges arise and a trade-off between global growing demands in agricultural production and the biomass demand for the energy and industrial raw material sector must be achieved (Diakosavvas et al., 2019). Müller and colleagues (2015) further support this view and argue that sustainable industrialisation and consumption, as well as production patterns, will largely depend on biomaterials and the ability to cope with the tremendous land requirements.

3 Research Design and Methods

3.1 Qualitative Interviews

In order to best answer the research question and to be of better assistance in the identification of solutions, expert interviews were conducted. In particular, the method of *semi-structured interviews* was chosen to approach the participants (Figgou et al., 2015). This enabled especially bottlenecks to arise, as this rather open format mitigates bias that might be imposed by overly structured questions, which may further result to be leading. As it is conventional in

semi-structured interviews, the participants were given enough room to digress and speak about their own topics and ideas. This way a clearer and more detailed focus on what is perceived as important to the particular interview partner could be achieved, while staying open to side ideas.
The data collected from the interviews had been systematically analysed in the framework of *qualitative content analysis* (Mayring, 2010). This involved inductive categorisation through coding systems. According to Mayring (2010) the investigation is interested not only in the *manifest* meaning of words or phrases but also in its *latent* underlying meaning.

3.2 Recruitment of Participants and Interview Guidelines

In the course of the research, seven experts interviews had been collected. Three of the experts worked in the field of natural sciences, covering natural resources use, agricultural economics and environmental policy perspectives. Not only did they provide different perspectives on the research question, but their diversity made it possible to draw parallels and identify complementing aspects throughout the different value-chain steps. This was then complemented by expert opinions from international organisations, involved first-hand in bioeconomy in sub-Saharan Africa. Furthermore, the production design step of the value chain had been covered by an expert in the design of agro-related products. Lastly, the participation of a social enterprise involved in accelerating sustainable development provided insight into end-of-life options.
The interview guidelines only involve a set of questions and topics that could be covered by every single participant (see Appendix A). Depending on their respective expertise the guidelines had been expanded. Benefitting from the diverse background, a more holistic view of the complex research question could be traced.

3.3 Limitations

Due to the limited sample of participants, the results of the study are not representative and exhaustive of complexity of the bottleneck identification in the value chain.
Furthermore, it could be that the institution's official opinion on sensitive topics could have influenced the interviewee's answers. In the course of the interview, this issue had been reflected by asking general and personal questions that gave the interviewees enough space to make their personal point.

4 Results

Following the selected research design, sub-categories have been identified. Figure 5 represents the visualisation of the frequency of all paraphrased passages according to each category (code frequency) in relation to the expert frequency by thematic categories. The extended version of the data is available in Table A1 and visualized in Figure A1 (both being in Appendix B).

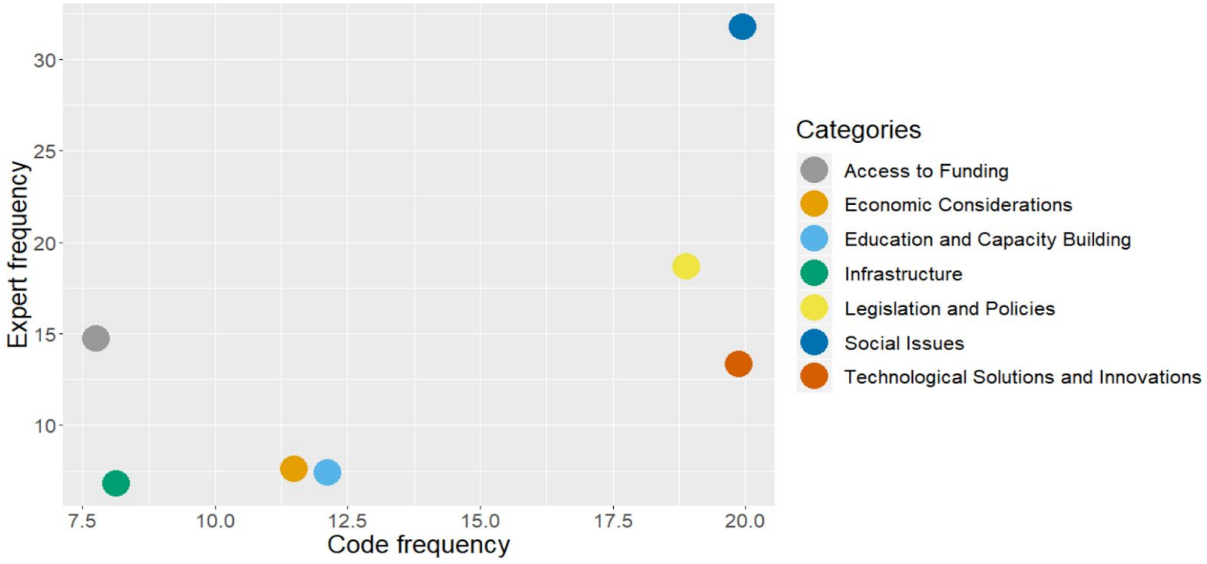

Figure 5. Content analysis according to Mayring (2010).

4.1 Social Issues

Social issues emerged as the main bottleneck in the perception of our interviewees. The risk of creating further social and economic discrepancies was mentioned as a pressing issue. Context specific solutions, together with participatory development, were generally regarded as a means of preventing it. In this sense, local public-private partnerships (PPP) are considered as an important option to foster local development. Moreover, in the context of agricultural production, it was explicitly mentioned that farmers need to represent one of the main drivers to any kind of innovation, and they need to be specifically supported by adequate policies. It has to be mentioned here that this refers to a bottom up approach and cannot be seen as a general concept. Solutions designed directly by those who are the intended to be positively affected could very well respond to the main challenge low income countries, and at that sub-Saharan Africa as a whole, are facing: food security and labour integration of SSA workforce. In this context, it was strongly underlined that bioeconomy can represent a viable approach, given the climatic and demographic pressure in agriculture, only if it is able to respond to these issues. On the same lines, hunger and malnutrition are critical social issues and are often tackled first as national interest, rather than sustainability issues: this reinforces the idea that bioeconomy needs to be tailored to local solutions and to respond to the pressing issues faced by the population. The importance of social innovations shall be determined as crucial to development in the perception of the experts. Further this statements was supported by the example that PPP and the fostering of local networks are empowering farmers to make their own decisions and design innovations, both technological and not.

The need for tailored solutions was often stressed. As an example, some of the interviewees mentioned personal experiences. For instance, adaptation was required on an assembly line where workers were provided with lunchboxes to ensure their wellbeing. This measure was enacted after observing employees passed out during working hours, due to the fact that they rather saved up salary for their families instead of spending it on their own nourishment.
In terms of holistic perspective, one expert believes all these aspects need to be considered in the framework of increasing migration fluxes directed from the countryside and agricultural areas to the cities, which will likely escalate due to climate change in the following decades. In this context, social strategies that retain the youth on site in productive areas need to be implemented to foster development, with the final objective of enabling farmers to do continue their business, were pointed out by the experts.

On the consumer side, cultural perception and low awareness can represent major obstacles: often products deriving from bioeconomy have difficulties in penetrating the market due to their novel nature. For instance, this applies to insects as food or feed in countries where traditional use of insects as food lacks. This could be overcome through the correct communication, such as media, in order to facilitate a different perception.

4.2 Technological Solutions and Innovations

Technology was specifically addressed in the questionnaire. While every interviewee thought it was important in the development of bioeconomy, some found it to be of great prominence in the future, to the point of technological implementation coming before, and therefore inspiring, policy making. For instance, a possibility could be supporting farmers in adapting technologies first and derive the specific policy framework building on that: the importance of aiding in developing local innovations, and therefore on site tailored technological solutions, was further stressed. Moreover, interviewees stressed on the possibility to adopt global innovations only as long as they are integrated and adapted to local conditions.

Innovation, in the shape of scientific research, was mentioned as a major bottleneck to the implementation. Technological lock-ins were named as an unintended consequence of a product development pipeline where, once strong scientific background and availability of funds are provided, innovations risk to arrest. Multi-cropping was taken as an example: while on paper it is beneficial from both an economic and an environmental point of view, the difficulties faced due to the lack of proper harvesting and processing machinery risk to nullify the advantages. Another side gave a more positive outlook for advancements in technology: especially traceability, as a shift towards circular economy, realized through automation processes, was pointed out for the future.
On the other hand, the interviewee with the most technology-oriented profile pointed out that technological solutions have already been developed, referring to the field of water management

in agriculture, and the obstacles that need to be faced are to be identified in funding and market uptake. Although, according to an expert, technology cannot be regarded as a "silver bullet", digitization can bring further benefits in knowledge availability and sharing. At the same time, it can provide more data to aid the design of approaches tailored, for example, to each farmer specifically.

4.3 Legislation and Policies

The role of the policymaker has been highlighted from most of the interviewed experts, making it the third most mentioned category of bottlenecks. Europe is already advanced in terms of legal framework, institutions and policy documents. However, in sub-Saharan Africa one expert observed a different situation: SSA countries are characterised by limitations in terms of policy documents and regulations available. Thus, a policy framework is needed for a successful implementation of bioeconomy as stated by all of the experts. Nevertheless, one expert working in an international organisation indicated that it is often the case that technology develops first and the policy environment adapts.

In order for the market and industry to be able to adapt to scientific solutions, public-private partnerships are necessary besides a framework. This policy support, already existing at research and policy level, helps the private sector to take up the new process: another interviewee described it as the "balancing role" of the government between public and private interests. One expert pointed out that policies can be, in this sense, seen as a trade barrier: for example, waste cannot be traded as such and this makes the retrieval and further insertion in other value chains of textile waste extremely difficult.

One further issue hindering policy making is corruption, to the point that one expert identified it is as the main barrier for low income countries. Moreover, they raised the question of how to ensure that those at the bottom of the wealth pyramid would receive the money necessary for implementation.

Overall, all experts agreed that policy makers need to target investments within the value chain in the right direction. Even though there was no consensus on the primary goal of interventions - whether it is the economic point of view (strengthen employment or value added), the sustainability aspect that relates to bioeconomy, or rather focusing on bigger challenges like hunger and malnutrition instead of climate issues - all of the interviewees could shed light on the necessity of action.

4.4 Education and Capacity Building

The results showed that sustainable solutions can only generate long-term impacts if the interplay of social actors is willing to participate. Thus, education is considered to play a pivotal role. One expert, from the academic field, emphasised the lack of public education and saw it as a potential barrier. Especially when it comes to novel concepts as bioeconomy and "green technologies", capacity building is needed and goes hand in hand with funding. The experts pointed out that by increasing capacity building, the discourse can be fostered as well as the demand for sustainable processes and products. Other interviewees concluded that support by the government and policy makers as well as improvements in education and skills have to be faced simultaneously to fulfill societal needs. Moreover, most experts expressed the necessity to raise the general awareness of the urgency of bioeconomy.

4.5 Economic Considerations

The interview outcomes showed that in high income countries, sustainable bioeconomy is principally regarded as a means to increase environmental sustainability and reduce the impact on natural resources. On the other hand, African countries are particularly rich in natural resources, which represent an under-exploited asset, and therefore are less interested in sustainability matters per se. According to the results, this translates to a specific interest in harvesting the biological resources in order to produce added value.

Moreover, job creation was highlighted as a major issue in SSA: once more, as concerning its social aspects, bioeconomy can only be viable if capable of labour integration. The textile industry, as an example, is very labour intensive. Therefore access to automation should go hand in hand with the employment of the local community and the implementation of the bioeconomic principles.

Furthermore, investments that are necessary to the implementation of a specific technology often entail too much risk: in this sense, the industrial actors need proper support from the state in order to take up new technologies.

4.6 Infrastructure

According to the respondents some problems of bioeconomy are not directly created by the market but are resulting of a lack of existing infrastructure. Due to limited control of the value chain of infrastructure very basic disturbance, as those of weather events (such as rain), can stop production processes. In a mentioned example a software company provided farmers with computers that were able to operate without constant power supply and could be charged mechanically. However, the operative system had to be downloaded from a cloud, that would have required internet connection. According to an expert this kind of issue is a form of

development that disregards local conditions and is faced continuously in practical application. However, without fixing basic infrastructure problems first, the implementation of solutions remains very difficult.
The interviewees stated that the private sector, as well as the government, need to focus on these issues and work together to resolve infrastructural problems, for instance through the private-public-partnerships approach.

4.7 Access to Funding

As the field of bioeconomy is rather novel in scientific discourse, investments in pilot projects and further studies will be necessary through appropriate measures. It was further pointed out that well funded research institutes in sub-Saharan Africa are insufficient in number. A strong science base was indicated as a precondition to the availability of funds. Additionally, public funding is crucial in order for the private sector to consider taking the risk of implementing new technologies.

Furthermore, the results emphasize the demand of monetary support for commercialisation. SSA faces a great barrier to the adoption of bioeconomy represented by the lack of knowledge on the potential benefits of its implementation, resulting in absence of local acceptance by the consumers. This has been confirmed by three experts that indicated the perception of community itself and media as pivotal for acceptance. Therefore, cultural differences and differences in the way how a community can or will accept products are very influential.
Another expert pointed out that funding for some issues, as textile recycling for instance, is frequently not considered of immediate interest and therefore a great quantity of manufacturing products end up in landfills after their end of use. The management of marketing and the handling of market uptake were also mentioned as a complex bottleneck: in the words of the interviewee, oftentimes those who are managing these aspects do not have the proper training to address these aspects.
Another interviewee, while agreeing on the funding issue and the importance of perception itself, pointed out that solutions have already been investigated in the scientific world. Most of the existing solutions are capable of meeting the climate and demographic challenges, however the lack of funding by international organisations and governments represents a major difficulty to their adoption.

5 Discussion

The emerged bottlenecks can be framed through the distinction between strong and weak sustainability (as presented in chapter 2.2). The successful implementation of sustainable bioeconomy, and therefore its contribution to the SDGs, largely depends on the adoption of

strong sustainability measures (Heimann, 2018). In this sense, the results obtained were largely in line with the previous research findings.

When it comes to access to funding, it was pointed out that funding is required in order to facilitate appropriate research in the areas of interest, technology adoption from the private sector, commercialization and waste management. This is confirmed by the fact that in the European Union, where bioeconomy is already widespread in national policies, many sectors of bioeconomy are indeed characterized by high market volatility and inherent risks, hindering its competitiveness. Access to finance is considered a key aspect of bioeconomic projects, private finance in particular, the lack of interest of the private sector representing a major obstacle. Therefore, further investigating the risks acting as barriers to investment and finance is needed (Leoussis and Brzezicka, 2017).

In this context, research and development strategies in order to foster the investments in technological innovations are widely discussed governance tools, given the resistance of the private actors to incur in the related risks under the given conditions (Bosman and Rotsmans, 2016).

Social issues-related bottlenecks were mentioned by the majority of the interviewees. The lack of basic human and social needs, such as nutrition, health care, education, together with food security and labour integration were identified as major issues. Moreover, the risk of creating further social and economic discrepancies, in the absence of a proper implementation design, was strongly highlighted. Beuchelt and colleagues (2013) shed light on this aspect in the context of gender equality, which was further addressed specifically for bioeconomy by Alvarez (2013). In these regards FAO (2018) has recently published guidelines on how to build gender sensitive value chains. Moreover, in terms of social disparity, the introduction of new labour saving technologies and mechanization in the absence of other employment opportunities could lead to increased poverty and migration to urban areas (Cotula et al., 2008; Deininger, 2013).

Public-private partnerships, participatory development and the importance of stakeholder involvement in the innovation design and strategies in order to retain youth on site, were cited as possible solutions. Validating this response, OECD (2019) states that the encouragement of public-private partnerships is a common point in the already existing national bioeconomic strategies. Furthermore, social innovations were deemed crucial in the upcoming decades to empower farmers and keep them in business. This is in complete accordance with the final report of the 2015 Global Bioeconomy Summit (GBS, 2015) that both stated that "technological and social innovations play a key role in achieving a sustainable bioeconomy" and strongly expressed the need for increasing and maintaining biobased value, namely "nutritional content per unit of food or feed", "natural and social capital" and "biological knowledge".

From the marketing point of view, the cultural perception and low awareness of the consumer were mentioned as major obstacles: in support of this finding Bracco and colleagues (2019) have highlighted that consumers are oftentimes not fully aware of the framework and related sustainability aspects of bioeconomy. This is also confirmed by Dietz and colleagues (2018), which identified misinformation as a major threat to the implementation of some bioeconomy-related technologies.
Cultural differences and differences in the way how a community can or will accept products were mentioned as very influential, together with market-uptake. This is supported by a wealth of literature (Daghfous et al., 1999) but specifically by Everdingen and Waarts (2003) who analysed the role of national culture in the adoption of innovations.
Grounding these findings in the SDGs framework, bioeconomy has the potential to strongly influence both negatively and positively SDGs belonging to the social sphere. SDG 1 (No Poverty), for instance, after the findings of to Cotula and colleagues (2008), could be positively affected: the creation of additional value and, therefore, increasing demand for agricultural goods, can result in higher prices, producing higher income for farmers. On the other hand, the risk of exclusion of parts of the workforce (such as in the case of gendered jobs) with the implementation of new technologies could negatively impact SDG 10 (Reduce Inequality) and SDG 5 (Gender Equality) (Dietz et al., 2018).

Technological bottlenecks were mainly traced back to lock-ins and implementation. Oftentimes, technologies and processes which have already been developed and would increase the efficiency of bioeconomy are perceived as inaccessible due to inefficient policies: this could potentially be addressed through innovation transfer (Dietz et al., 2018).
Lack of scientific research and funding were also mentioned as causes for the absence of implementation. This is especially interesting since, according a report recently produced by OECD (2019), one of the core commonalities between already existing bioeconomic strategies are indeed the support to research, innovation and technology.
The successful implementation of global innovations was conditioned to their integration and adaptation to local conditions: this is supported by the fact that context-specificity of the use of bio-based technologies and principles is regarded as a major point determining the positive or negative effect of the implemented solutions (Dietz et al., 2018).
Furthermore, digitization was mentioned as a viable tool to create tailor-made solutions (such as. the use of precision agriculture to inform farmer choices). Indeed, digitization and specifically precision agriculture are regarded by Diakosavvas (2019) as a major component of bioeconomy.
One of our interviewees stressed that technology should not be seen as a "silver bullet": this is in line with the position of Pyka (2017) and Schlaile and colleagues (2017): while technological development is crucial in the transformation process towards sustainability, the complex nature of the challenges humanity is facing implies that technological substitution alone is not going to be sufficient in order to tackle them.

All experts interviewed strongly emphasised the role of the policymaker and the necessity of action. In particular, the involvement of policy makers as intermediaries in public-private partnerships was mentioned. Such partnerships facilitate the transfer of scientific solutions to the market and industry and help integrating local feedback throughout the adoption of bioeconomy. The literature confirms that coordination and collaboration in policy development must take place along the entire value chain (Food and Agriculture Organisation, 2013; Ertz and Sarigöllü, 2019). According to experts, though, policy must be carefully designed to create an environment that enables the introduction of the bioeconomy. The interviewees could neither agree on the primary objective of such interventions nor on the right timing (for instance in terms of policy implementation before/after technology development). This again underlines the context-specific nature of adoption processes.
In addition, Olken and Pande (2012) and the respondents identified the high degree of corruption in low income countries as arising bottleneck. This can be supported by this year's average SSA corruption perception index, which sees it as the worst scoring region worldwide (Transparency International, 2019).

Economic bottlenecks dealt primarily with potential synergies and tradeoffs of employment. There has been consensus in literature and expert interviews on the potential benefits of introducing new employment opportunities to small farmers (UNIDO, 2009) and achieving poverty reductions (Wiggins, 2005). Further, Campbell and colleagues (2017) highlighted value adding, through for instance development of processing industries, as a potential for boosting rural employment.
Some interviewees indicated concerns about labor integration. As the agro-industry in SSA is highly labor-intensive, especially technological-oriented (or more specifically automated) solutions entail the risk of having negative impacts on the employment in the local community. One expert highlighted that bioeconomy can only be viable if capable of generating employment options. As pointed out by Dihel and colleagues (2018) "65 percent of the labor force is employed in the primary sector, accounting for 32 percent of gross domestic product". Therefore, a shift of activities which already possess existing comparative advantage such as agro-industry to other ones might involve adverse economic impacts.

Interviewees regarded education, in terms of acquiring necessary technical skills, and capacity building as well as knowledge of its potentials, as largely important. This is in accordance with SDG 4 (Quality Education). Indeed, the European Commission's (2018) latest document on the updated bioeconomy strategy clearly states that "the systemic and cross-cutting nature of new and emerging bioeconomy approaches and new value chains will need new education and skills". These skills will need to be adjusted to the different aspects of bioeconomy in order to promptly and flexibly respond to the necessities of the sector. Fostering higher education and public-private-partnerships, as well as the involvement of social partners, which were also mentioned by our interviewees as stark necessities, will be crucial. This is especially true for the

SSA countries: the general lack of skills, funding and infrastructure represents a major constraint to the development of an adequate bio-based economy. This includes both formal training, from secondary school onto postgraduate training and the resulting basic and applied research (Bakubung Workshop Report, 2017).

The inadequacy or even lack of existing infrastructure had been identified by the interviewees as the final bottleneck. If infrastructures are not available, bioeconomy adoption will not be possible along the value chain. In order to ensure a successful adoption, it must be investigated whether the existing options are sufficient. That is also confirmed by Kouwenhoven and colleagues (2012), who confirm the necessity to tackle infrastructure related bottlenecks. The Food and Agriculture Organisation (2017) further stresses the crucial role of agricultural infrastructure in withstanding climatic challenges.
In addition, the experts agreed that the private sector and government are co-responsible for addressing infrastructure-related challenges. In this sense, one possibility could be public-private partnerships. Supporting this response, Calderon and colleagues (2018) emphasize the existence of the "large gap in terms of quantity, quality and access to infrastructure" in SSA and the possible growth, productivity, inequality and poverty effects that could be attained when closing this gap.

6 Conclusion

Being able to cope with future demographic and climatic challenges will require agro-industry in sub-Saharan Africa to shift towards a more efficient and sustainable use of natural resources. Bioeconomies have been promoted as an essential instrument to address those challenges. Not only environmental impacts of the adoption of bioeconomy are highly significant, but so is the opportunity to reduce poverty and inequality through job creation and strengthening of the economy. To realise the potential of a sustainable bioeconomy, possible trade offs throughout the value chain need to be considered and minimized.

Overall, results have highlighted the presence of multiple bottlenecks, belonging to the economic, social, cultural, developmental, financial and technological spheres. Social bottlenecks were identified as the most pressing by the interviewees. The lack of basic human and social needs, such as nutrition, health care, education, together with food security and labour integration were indicated as major issues. Moreover, the risk of creating further social and economic discrepancies, in the absence of a proper implementation design, was strongly highlighted. These results are mainly in accordance with literature findings related to sustainable development and sustainable bioeconomy. Moreover, the intertwinement and often co-dependency of bottlenecks illustrated in the results clearly demonstrate that sustainable bioeconomy represents a viable option to achieve development only in its integrated form, and, therefore, via the adoption of a hard sustainability approach.

In conclusion, this study highlights the necessity of adaptation in order to favour bioeconomy. In other words "we need a pervasive transformation encompassing the dynamics and complementarities of technological, organizational, economic, institutional, socio-cultural, political, and environmental systems" (Urmetzer et al., 2020). Bioeconomy represents an interesting opportunity of development for SSA, granting access to rural development, value addition and job creation if correctly implemented. Besides, bioeconomy will only be successfully implemented if it will show potential in responding to the pressing issues faced by sub-Saharan Africa. Bearing in mind that the next few decades will be decisive in shaping and implementing a new and transformative global agenda, in response to the increasing pressure of climate and demographic change, bioeconomy could very well increase the resilience of sub-Saharan African societies to global socioeconomic and environmental challenges.

These in turn depend on the successful implementation of policies and development strategies, which should be aimed first and foremost at creating an enabling environment for the development of bioeconomy: provision of basic infrastructures, fostering private-public-partnerships and education measures are the most urgent actions.

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Appendix A

INTERVIEW GUIDELINE

Introduction

- Could you please briefly tell us about your role and the work of your institution?

General knowledge of solutions applied to agro-industry in SSA in the framework of bioeconomy

- How are you involved in the bioeconomy of SSA?
- Do you think bioeconomy is a viable approach to climate change-related risks in the agro-industry of -Saharan Africa?

  If yes, do you think the adaptation or the mitigation component are prominent?

  If no, why?
- Which have been the main challenges that you have faced so far in the implementation of bioeconomy? Which challenges do you think will arise in the next 10 years?
- What role technical solutions will or can play in the future of sustainable agriculture in SSA?

Personal experiences and views

- In the last 5 years, did your field of work evolve to adopt new approaches to bioeconomy implementation?

  If yes, explain to which extent those solutions capture future risks.
- Which have been the main challenges that you have faced so far in the implementation of bioeconomy? Which challenges do you think will arise in the next 10 years?
- What's your personal point of view on sustainable solutions in the future of agriculture?

Appendix B

Category	Subcategory	Codes	% of all codes	Experts	% of all experts
Social Issues	Cultural perception/take up	13	15,85	5	10,00
Technological Solutions and Innovations	Impact of technological solutions	11	13,41	7	14,00
Social Issues	Context-specific design	9	10,98	6	12,00
Legislation and Policies	Framework, institutions and policy documents	8	9,76	4	8,00
Access to Funding	Commercialisation	6	7,32	3	6,00
Infrastructure	Infrastructural problems	6	7,32	3	6,00
Legislation and Policies	Public-private partnerships	5	6,10	3	6,00
Access to Funding	Private sector implementation	4	4,88	2	4,00
Social Issues	Participatory development	4	4,88	4	8,00
Economic Considerations	Value Added	3	3,66	2	4,00
Economic Considerations	Employment opportunities	3	3,66	2	4,00
Education and Capacity Building	Capacity building activities	3	3,66	2	4,00
Education and Capacity Building	Investment in Education and Skills	3	3,66	3	6,00
Access to Funding	Strong science base	2	2,44	2	4,00
Legislation and Policies	Corruption	2	2,44	2	4,00
			100,00		**100,00**

Table A1. Content analysis according to Mayring (2010). Codes refer to the number of times a topic was mentioned, regardless of the expert. Experts refers to the number of experts that mentioned the topic.

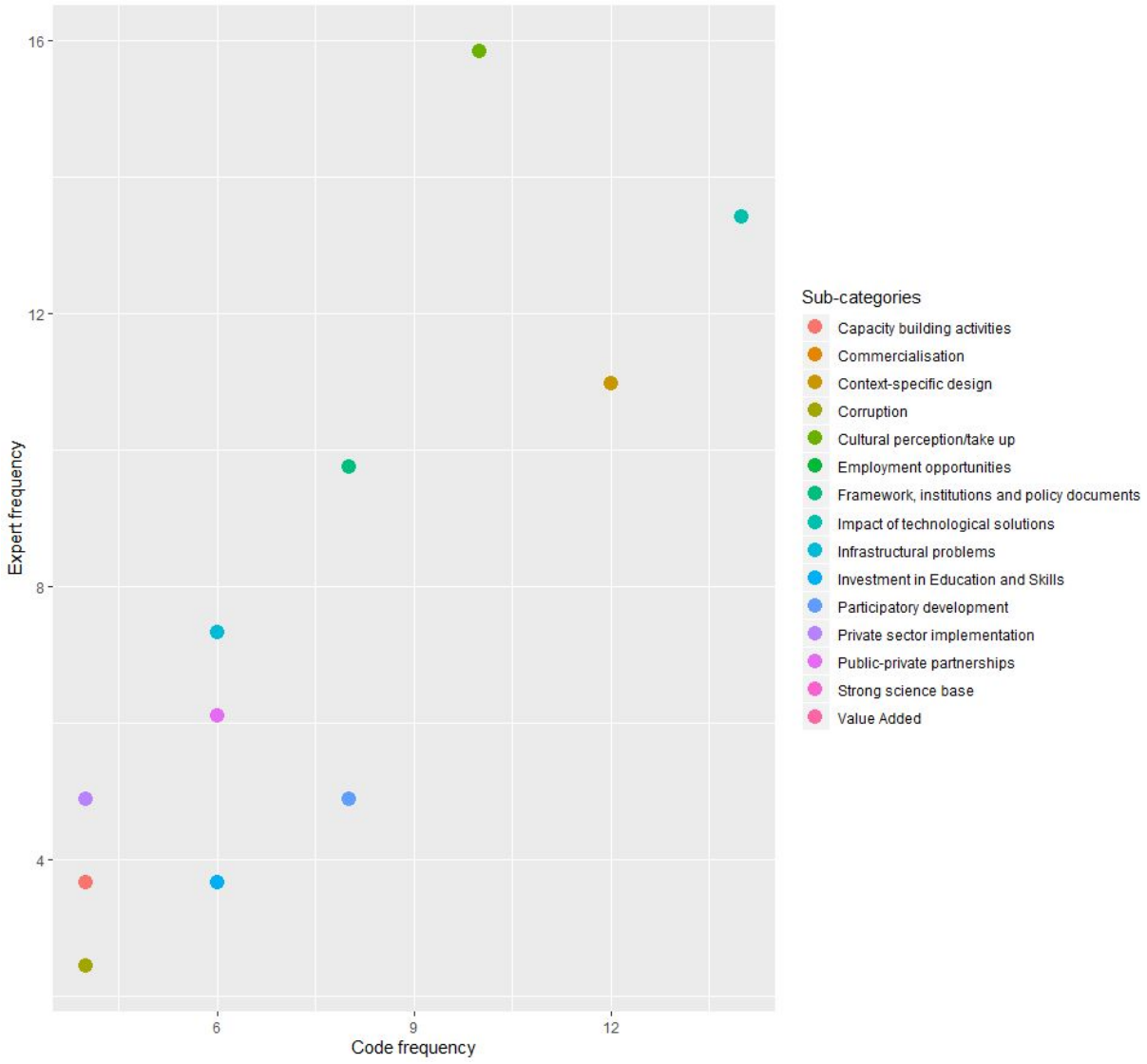

Figure A1. Visualisation of content analysis relative to Table 1 (Appendix B).