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Transnational innovation systems for bioeconomy: insights from cassava value chains in East Africa

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In this study, we analyze the purpose, challenges, and opportunities of transnational innovation systems using cassava as the case study crop in the East Africa region. Cassava scientifically referred to as *Manihot esculenta Crantz*, is an important food security crop for the poor and vulnerable and a potential building block for advancing the bioeconomy in Africa and the global South. Semi-structured interviews with researchers, government official, and small and medium enterprise representatives from the region were done to determine their level of collaborations with other partners across the region and the opportunities and challenges for transnational innovation systems along the cassava value chain. The selection of interviewees followed a purposive sampling technique according to their knowledge on transnational innovation in the cassava value chain. This was corroborated by a focused literature review on innovation systems concepts gathered from scholarly literature. The findings show that transnational collaborations and innovations in the East African region offer opportunities for expansion of biomass production, bioprocessing, and value addition to the rich bioresources available. Collaboration across borders and transnational innovation systems were found to play an important role for advancing and/or upscaling cassava breeding, growing, value-adding products and novel processing methods and contributing to a growing East African bioeconomy. Other than the regional policy challenges, organizational and cultural barriers were more prominent in venturing, participation, and involvement of parties and users in transnational innovations. These findings draw attention to the often unnoticed, but vital, role that institutional and policy frameworks play in initiating as well as supporting transnational innovation systems that address issues of current and future global concern. Therefore, appropriate policy environment and partnerships that offer opportunities for synergy and complementarity are vital for building effective transnational innovation systems that enhance the sustainability of production, value addition and end-uses of biobased cassava products.

KEYWORDS

transnational innovation systems, cassava, international collaboration, bioeconomy, bioresources

1 Introduction

The bioeconomy is a key element of the long-term transition to sustainability and is broadly conceived as involving cross-cutting innovation that adds value using bio-based resources and processes across all economic sectors (International Advisory Council of the Global Bioeconomy Summit 2018–IAC-GBC, 2018). Advancing and implementing sustainable bioeconomy is a challenging undertaking that requires broad international collaboration not only for research but also for integrating bioeconomy principles into multilateral policies and institutions in support of climate aims and Sustainable Development Goals (SDG) (El-Chichakli et al., 2016; Dietz et al., 2018).

This comprehensive view on bioeconomy has high relevance in the global South due to the high concentration of biodiversity, the large size of the agricultural and biobased sectors in terms of gross domestic product (GDP), employment, and potential for pro-poor economic growth, and the need to use land and biomass more productively to achieve climate resilient and equitable development pathways (Virgin and Morris, 2017; Van de Ven et al., 2019; Johnson et al., 2022). While the bioeconomy is developing, the constraints of a changing climate alongside the need to provide food and energy for an expanding world population pose significant policy challenges and suggest quite different bioeconomy pathways in different regions (Philp, 2018). The high priority associated with food and energy security at national levels, especially in the African context, has contributed to the tendency in analysis or research as well as in actual bioeconomy and bioenergy strategies around the world to be rooted at national level (Kline et al., 2017).

Bioeconomy development usually requires raw materials that are sourced locally or at least nationally due to costs and bulky logistics, unlike other sectors such as manufacturing where goods are traded more easily (Devaney et al., 2017). However, there is also a rationale for international cooperation and governance (if not trade), considering that pollution, land use, food security and biodiversity impacts of the bioeconomy have a clear transnational component (Von Braun and Birner, 2017). Furthermore, unlike the case for wealthier countries, smaller countries in the global South are more likely to succeed when they pool their bio-based resources, technical capacities, and market opportunities to aim for comparative advantage in a regional rather than national context (Johnson, 2017). For instance, a regional bioeconomy strategy for Eastern Africa was recently developed (EASTECO, 2020) while the European Union (EU) has had a bioeconomy strategy for over a decade (Bell et al., 2018) thus pointing to advantages of collaborating transnationally on bioeconomy pathways.

Innovation is considered a fundamental prerequisite for the bioeconomy to become a transformative force of change toward sustainability, and in this context, it is viewed broadly and not only in relation to technological innovation (Detoyinbo et al., 2022; Mittenzwei, 2022). The wider construct of *innovation systems* is often used to consider the diversification of applications, the management of resources and other issues (Van Lancker et al., 2016). In the context of sustainability transitions, innovation concepts have also been applied using the multi-level perspective for classes of bio-based products and processes (Wydra et al., 2021). Differences in innovation platforms lead to different bioeconomy pathways in the longer-term (Bauer, 2018). There is also a key role for technology transfer and trade to spur innovation across borders, but the emerging taxonomies for the bioeconomy and the associated systems for sustainability certification may pose barriers to international collaboration and governance (Philp and Juvančič, 2021; Vogelpohl, 2021).

The role of innovation systems operating across borders is thus of special interest for bioeconomy development in the global south, and especially for the agricultural bioeconomy due to food security issues. In addition to the many international agricultural networks around the world, there are also international networks that operate in other sectors, such as health and sanitation, which are connected to international development cooperation efforts and use various intermediaries to effectively facilitate transnational innovation systems (Van Welie et al., 2020). By considering a particular sub-sector or crop, we can analyze the purpose and functions of transnational innovation systems in more detail.

As a case study, cassava is a crop of special interest in the African development context due to the risks posed by climate change: its durability, flexibility, and high resistance to biotic (e.g., droughts) and abiotic (e.g., pests) stressors have made it a key element of food security for the poor and the vulnerable and a potential building block for advancing the bioeconomy in Africa and the global south (Dixon et al., 2001). Furthermore, the high biomass productivity of cassava and its versatility for applications in energy, health and other sectors has led to a wide variety of research and development (R&D) platforms and associated innovation approaches to add value and enhance its utilization (Poku et al., 2018; Bicko et al., 2021; Padi and Chimphango, 2021a,b; Padi et al., 2022).

Efforts have been underway in eastern Africa to coordinate research and product development using cassava as raw material, with the aim to simultaneously improve productivity and diversify the uses and application of cassava. Productivity of cassava, however, remains low in the region due to issues such as lack of capital for investment and poor agronomic practices (Nuwamanya et al., 2016; Nakabonge et al., 2018). The case of cassava in eastern Africa can help to illustrate potential synergies between structural transformations in agricultural practices using not only the global bioeconomy framework but also a transnational lens focusing on innovation. We therefore discuss in the following subsections the theory of transnational innovations, the framing of transnational innovations, definition of actors and institutions for transnational innovations and the importance of cassava as a bioeconomy resource.

2 Theory of transnational innovation

Innovation is a highly researched topic occupying scholars of many disciplines. Ever since Joseph Schumpeter's reflections on innovation as a "new combination" of factors such as production materials or industrial processes and the prominent role of the individual entrepreneur played in his theory (Schumpeter, 1934), understanding of innovation has become more nuanced. Scholars like Freeman, Edquist and Lundvall opined that innovation is best understood as a process embedded in a network of both public and private institutions (Freeman, 1987; Lundvall, 1992; Edquist, 1997) where firms continuously gain, develop and exchange various kinds of knowledge, information and other resources" (Edquist, 1997). Here, the term "institutions" is understood as describing both concrete actors such as research institutes, firms, government ministries or consultancies and in a social sciences sense as describing cultural

codes, norms and rules that structure our behavior (Edquist and Johnson, 1997). However, not only does the network of institutions play a role in innovation, but the concept can also be investigated on different scales.

Authors have popularized the notion of national innovation systems (NIS), while more recent studies have focused on the Regional Innovation Systems (RIS), regional here meaning mostly sub-national. For RIS scholars, knowledge and expertise is thought of being often geographically concentrated on a sub-national level (Asheim and Gertler, 2006) because those centers of innovation also known as innovation clusters, are often embedded in a distinct regional culture defined by common institutions, norms, practices, and trust (Cooke et al., 1997; Cooke, 2001). This common culture and these norms would thus create contextual knowledge which proves to be bound to specific geographic area (Asheim and Isaksen, 2002). This regional aspect of knowledge creation and sharing is thought to be especially important when it comes to "tacit knowledge," which depends more on face-to-face interaction, shared conventions, and norms (Asheim and Gertler, 2006) or for "synthetic knowledge" which emphasizes the novel combination of already existing knowledge particularly in the engineering and machinery field (Asheim and Gertler, 2006).

However, in the globalized world of the 21st century where new communication technologies make the sharing of information and knowledge easier than ever, scholars also argue that innovation is increasingly connected to the international level (Carlsson, 2006; Fromhold-Eisebith, 2007). Some scholars therefore propose to see all the levels of innovation connected transnationally because of the inherent connectedness of actor networks on all levels (Binz and Truffer, 2017). While global innovation system might be relevant for some value chains, technologies and practices, other value chains, technologies and practices might be much more bound to a specific geography especially for agricultural products and practices which often depend on highly localized innovation, knowledge, and expertise, therefore being less connected to the global innovation level. This has raised concerns on the effectiveness of innovation systems across borders (Trippl, 2010). Although cross-border regional innovation systems (CBRIS) face several challenges (such as different institutions, languages, or infrastructure on both sides of a border as well as diverging economic development) they are also important in making use of complementarities in industry- and knowledge bases (Trippl, 2010). This, however, depends on how integrated both innovation systems across borders are and how policies on the different sides of such borders stimulate innovation activities (Lundquist and Trippl, 2013). While borders still matter in terms of a cooling effect on innovation collaboration, Hjaltadóttir et al. (2020) show that some regions compensate for their sub-optimal geographical location (far from urban centers and/or centers of innovation) by collaborating increasingly across borders to compensate for this border effect.

2.1 Framing of transnational innovation

This paper thus focusses on innovation systems in a global context from a transnational perspective here referred to as Transnational Innovation Systems (TNIS). Coe and Bunnell (2003) describe three "domains" of transnational innovation networks each of them consisting of different key actors which employ different mechanisms of knowledge transfer such as transfer via institutions, migrant workers, or "discursive" players such as think tanks or media (Coe and Bunnell, 2003). Others have looked at innovation in transnational companies (Bartlett and Ghoshal, 1990) or at how specific institutions such as universities could cooperate transnationally (Cai et al., 2019).

Despite the apparent novelty of the Transnational Innovation Systems concept, we identified the transnational perspective as a good fit for the research questions in this study. First, the term "transnational" is often thought of as going beyond the term "international" in political science. In international relations, the term transnational is used to denote a concept of international relations which goes beyond nation states as central agents (Nye and Keohane, 1971) and where sub-national actors and non-governmental actors play a key role, at least conceptually (Clavin, 2005). Risse-Kappen (1995) defines transnational as "regular interactions across national boundaries when at least one actor is a non-state agent or does not operate on behalf of a national government or an intergovernmental organization. We use the term transnational innovation systems because we do not only focus on cooperation between governments on bioeconomy innovation, but also on cooperation arrangements across borders between other stakeholders such as private sector actors, knowledge providers (universities, think tanks, international research institutions) or non-governmental organizations (NGOs). Second, with bioeconomy pathways being per definition cross-sectoral, involving many scales and regions, Regional Innovation Systems (RIS) perspectives are too small a scale for our investigation. The same holds true for the cross-border regional innovation (CBRIS) systems perspective. The term transnational innovation system (TNIS) can link the local, sub-national level to the global level as suggested by (Binz and Truffer, 2017) as it includes many more actors and networks as a National Innovation Systems (NIS) perspective. Therefore, transnational innovation systems are defined here as innovation systems which have an important cross-border component (i.e., where stakeholders collaborate in a regular manner across national borders) and where stakeholders other than policy makers and private sector stakeholders play a prominent role. Those stakeholders include knowledge providers, NGOs, interest groups, universities and think tanks.

2.2 Actors and institutions of transnational innovation

There is no widely used taxonomy of what kind of actors are relevant for an innovation system in the literature. Edquist and Johnson (1997) differentiate between "organizations" and "institutions" (Edquist and Johnson, 1997) with a few examples. Labor unions or universities would be organizations, while laws and traditions would be institutions. Quite obviously, companies or small and medium enterprises (SMEs) are thought of being part of the innovation system since many case studies evolve around them (Grillitsch and Trippl, 2014). The Organization for Economic Cooperation and Development (OECD) suggests that actors in innovation systems include "firms, public and private research organizations, and government and other public institutions" (OECD, 1999) although it seems that institutions in their usage are not norms and traditions but governance entities such as ministries. Looking at innovation from a national perspective, Kuhlmann and Arnold (2001)

categorize actors in their study about innovation systems under "demand" (consumers), "framework conditions" (financial environment), "industrial system" (large vs. small companies), "Infrastructure" (banking), "political system," "Education and Research" and "Intermediaries (research institutes; Kuhlmann and Arnold, 2001). Using these actors as a basis, Warnke et al. (2016) add to this understanding by including actors such as labor unions, "social innovators" or other "intermediary" actors in their ideal innovation system (Warnke et al., 2016). Similarly, Binz and Truffer (2017) include NGOs and consultancies in their list of important innovation system actors (Binz and Truffer, 2017). Based on these slightly differing innovation system schematics, this study uses an innovation system ideal type, based on the literature cited above.

2.3 Importance of cassava as a bioeconomy resource in East Africa region

Cassava, scientifically referred to as *Manihot esculenta Crantz*, plays an important role as a food security crop for subsistence farmers (Kriticos et al., 2020) and is the world's fourth most important staple crop after rice, wheat, and maize (Mtunguja et al., 2019). It grows in tropic and sub-tropic regions of the world (IFAD, 2010) with global annual production amounting to about 278 million metric tons (FAOSTAT, 2020). Currently, the global cassava market grows at a rate of about 3.2% and is currently worth over $4.5 billion (Ikuemonisan and Akinbola, 2021). In Africa, cassava is the second most important food staple in terms of calories consumed *per capita* and a major source of calories for roughly two out of every five Africans (FAO and IFAD, 2005). The United Nations' Food and Agriculture Organization estimates that 61% of the annual global production of cassava comes from sub-Saharan Africa (FAOSTAT, 2020) of which 75 percent of Africa's cassava output is harvested in Nigeria, the Democratic Republic of Congo, Ghana, Tanzania, Uganda, and Mozambique (FAO and IFAD, 2005). The density or prevalence of cassava production in different areas is shown in Figure 1.

Cassava, originally from Latin America, produces edible tuberous roots with a high starch content (85–90% of dry weight) and small amounts of vitamins and protein. The cassava leaves are rich in protein, can be a significant fodder contribution. Cassava can be harvested within 4 to 5 months of planting without adversely affecting root production, yielding up to 10 tons of dry foliage per hectare during good growing conditions (Wydra et al., 2021).

In the wake of climate change, Cassava is more preferred by the small-scale farmers in East Africa due to its tolerance to frequent drought conditions and the ability to grow under low fertile soils where most crops fail (Fermont et al., 2009). It has successfully been incorporated into many farming systems compared to the traditional staples such as millet and yam because of its high adaptability to the local farming environment and high tolerance to erratic weather condition (Jarvis et al., 2012). In addition, its harvest time flexibility looks convenient for farmers who consider cassava as a food crop that can easily be converted to income (Abass et al. 2018). It has no definite maturation point and therefore, harvesting may be delayed until market-, processing or other conditions are more favorable; this flexibility means cassava may be field stored for several months or more. It is, thus, highly acceptable in the rural areas as a food security crop because of this flexibility and adaptability to diverse climatic conditions (Nakabonge et al., 2018).

Cassava production and its food, nutritional, and industrial positioning as a climate smart crop in East Africa faces major challenges. The production challenges are associated with the increased prevalence of pests and diseases, lack of quality pathogen-tested planting material, ill-defined and poorly functional seed system structure, and lack of statutory regulations to guide the cassava seed value chain. High post-harvest losses due to the fast decomposition of harvested cassava is also a major problem necessitating rapid processing which involves a range of techniques such as drying, cooking and fermentation of cassava to improve its shelf life, reduce weight, and enhance its overall value. Most of the processing is however done locally, using traditional technologies and limited access to modern processing techniques and value chains. Thus, despite the recognition of the high value of cassava, East African countries have so far only to a limited degree responded to the opportunities of using cassava cultivation, processing, and value addition as an engine for agricultural growth, job creation, and the development of a modern bioeconomy. While commercial enterprises using cassava as an industrial crop have been quite successful in countries like Brazil and Thailand, such attempts have failed in Africa, including East Africa.

However, despite production, processing, and market challenges for cassava East Africa, there are significant opportunities to improve cassava productivity and processing through development of cassava based biorefineries producing several types of industrial graded starch, biofuel, and other biobased products. Such new value chains would also connect cassava smallholders to emerging and growing markets in the region and internationally for products such as novel cassava food and feed products and starch-based bio packaging products. For this to happen, the creation of collaborative platforms for increased cassava productivity and value addition, sharing and learning from other regions will be important through integration of training and extension for farmers, shared expertise, infrastructure, and business incubation facilities. Private-public partnerships for technology and industrial development will also be key in realizing the potential of cassava cultivation and processing.

3 Methodology

The approach for this research was elaborated in an iterative process using some well-established social sciences methodologies. First, we conducted a focused literature review to get an overview of innovation systems concepts that existed in scholarly literature. We used google scholar to identify relevant literature and then employed a backward snowballing technique to find more sources on a given topic (Wee and Banister, 2016). This facilitated the incorporation of quantitative, qualitative, and mixed methods literature to evaluate the purpose, challenges, and opportunities of transnational innovation systems. The retrieved data encompassed several aspects related to cassava value chain in East Africa, as well as strategies for transnational innovations. The acquisition of primary sources for this study involved doing a comprehensive search across many scientific and educational databases. The process involved checking for duplicates, followed by a review of the titles and, if applicable, the abstracts of the papers. Subsequently, a more thorough

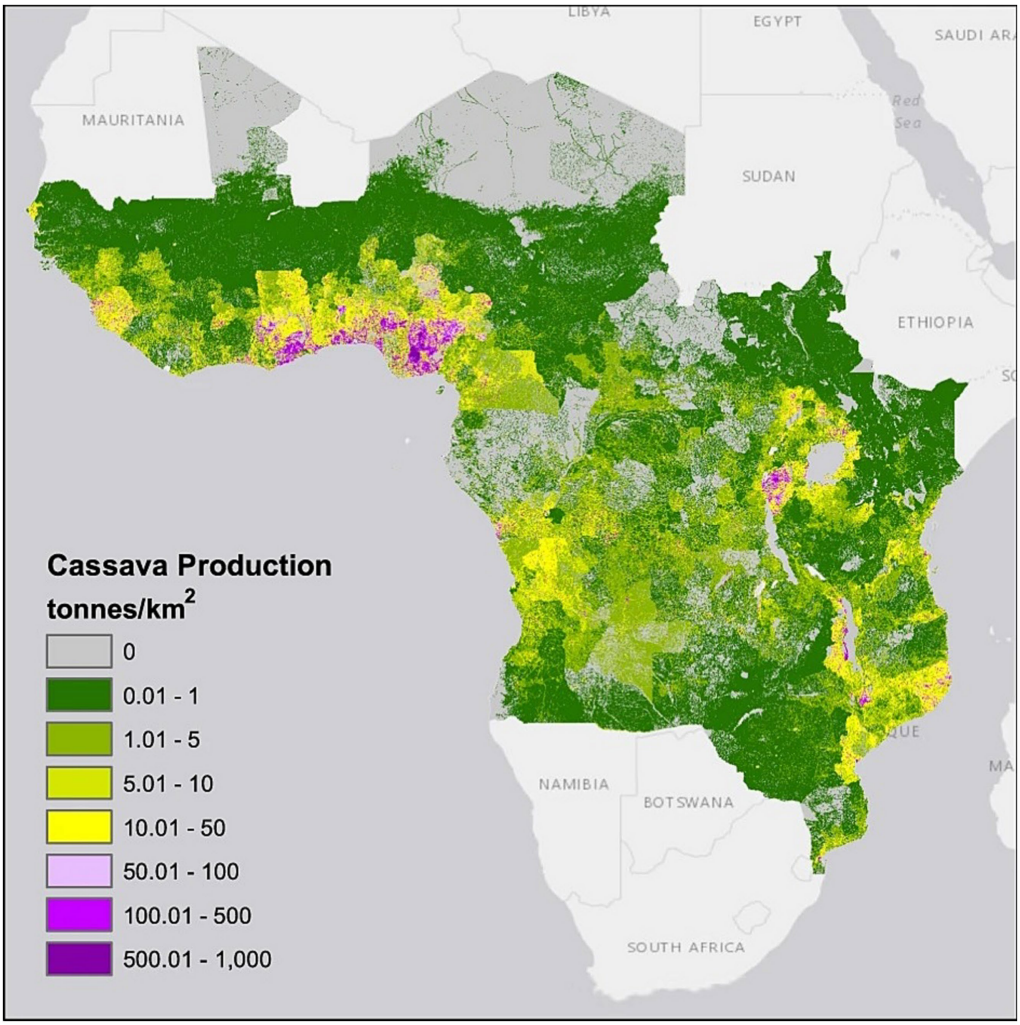

FIGURE 1
Density of cassava production in sub-Saharan Africa, source: (Szyniszewska, 2020).

reading of the papers was conducted. Only manuscripts that specifically addressed the challenges and opportunities associated transnational innovations along the cassava value chains were included for further analysis. Moreover, the search for the articles was mainly for those covering the East Africa region. Based on this literature review, we collaboratively defined our understanding of transnational innovation systems and categorized the stakeholders to consider in the study, based on the reviewed literature. The focus of analysis was on cassava collaborations in East Africa region. The regional focus was chosen mainly because several of the authors had long-standing research experience in the region and a good network of contacts. Furthermore, the development of the bioeconomy strategy for East African in recent years offers a platform for transnational innovation (EASTECO, 2020). Moreover, a regional focus on East Africa could enrich the innovation systems literature with some insights from the global south, which is still underrepresented in innovation systems literature (Wakunuma et al., 2021).

Cassava was chosen as the crop in focus and the unit of analysis because of the importance for the crop in sub-Saharan Africa (see sections 2.-3). Once we decided on the regional focus and the innovation system focus, we then proceeded to map important stakeholders in the transnational cassava innovations in East Africa. As a next concrete step, we designed a MS Excel based research sheet to facilitate the systematic mapping of important stakeholders in the East African cassava innovation system. The sheet included information about the sectors of activity of each stakeholder, the connection the stakeholder had to other stakeholders active in the casava value chain (information gathered from official documentations and web pages), using the categories described in Figure 2 such as stakeholders from the infrastructure system (banks, incubators, finance providers), the political system (governmental agencies, ministries), Intermediary actors (NGOs, cooperatives), industrial system actors (SMEs, companies) and stakeholders from the research system (universities, think tanks, technology centers).

Once this initial mapping was done, using web searches, webpages of stakeholders as well as the expertise of our own professional network, we proceeded to conduct a series of semi-structured interviews with experts from the identified stakeholder institutions and beyond. A total of 17 key stakeholders were interviewed to represent the organizations and systems mentioned. The main

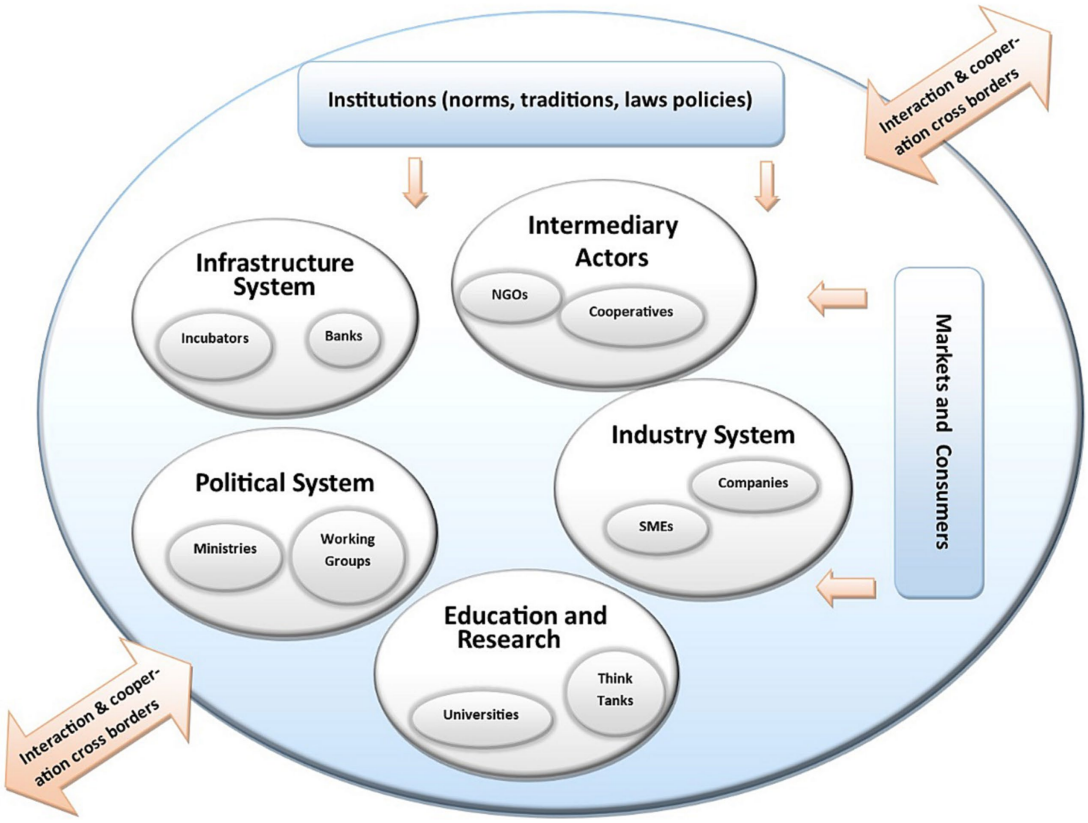

FIGURE 2
Graphic representation of actors in a transnational innovation system.

objective was not to draw the most complete picture of transnational innovation in the cassava value chains, but to collect narratives of the status of transnational cooperation in East Africa, its associated challenges and opportunities from local experts thus enriching our understanding of transnational innovation systems with a distinctly local perspective. The selected stakeholders were interviewed between the months of September 2021 to October 2022. The main objective of the interviews was to gather more information on how stakeholders identified in the previous steps collaborated across national borders in the cassava innovation system and to identify important stakeholders in East Africa in the cassava value chain and research environment which escaped our attention when performing the online research.

Although we applied scientific rigor and due diligence, several limitations of this methodology must be noted. It is likely that several other papers and published articles may not have been accessed and analyzed during the literature review, especially those that they may fall in the gray literature. Although this does not invalidate our concept of a transnational innovation system, it might be the case that nuances, and some conceptual insights might be missing from our analysis. Moreover, since we employed purely qualitative social sciences-based methods, it is highly likely that other actors in the East African transnational cassava innovation system were not captured. This is simply because, theoretically, the list of stakeholders is endless and never complete due to the sheer number of environments they are active in and because stakeholders entering and exiting the innovation system regularly. However, we would argue that this paper is a first attempt to map out certain important stakeholders in the cassava innovation system in the region and provide important understanding of the cassava innovation system in East Africa, its important actors, and its transnational dynamics.

The initial mapping exercise identified several important actors who worked across borders in the cassava innovation system (Table 1).

In the education and research system, several universities were identified such as Makerere University in Uganda, the University of Dar es Salaam in Tanzania, the Jomo Kenyatta University of Agriculture and Technology, and the University of Nairobi in Kenya, all having dedicated cassava research programs and collaborating with other universities across the region and with each other on the cassava innovation system. In the education and research system, technology, and research centers such as *BioInnovate Africa*, the *International Institute of Tropical Agriculture*, the *International Livestock Research Institute (ILRI)*, the *International Potato Centre*, the *International Centre of Insect Physiology and Ecology* or the *International Centre for Tropical Agriculture (CIAT) were also identified*. While some of these centers are affiliated to universities, others have been established by international donor organizations such as *Bio innovate Africa* at International Center of Insect Physiology and Ecology in Nairobi, Kenya with funding from the Swedish Development Agency (SIDA) or are even truly transnational organizations like CIAT in the sense that their work is across border and incorporating many non-state stakeholders and actors. For instance, CIAT hosts the *Global Cassava Partnership for the 21st century* which collaborates with many East African countries such as Kenya, Uganda, Burundi, Rwanda, and Tanzania on cassava innovation.

TABLE 1 Stakeholders in innovation systems and their role in the bioeconomy.

	Drivers	Enablers	Regulators
Researchers/educators	Sharing/collaboration on basic science/research	When partnering with industry and SMEs	N/A
SMEs/industry	Patented technologies and innovative practices	Public-private partnerships and joint ventures	N/A
Intermediary actors	N/A	International donors, industry trade groups	NGOs, civil society,
Government/political	N/A	Articulated strategies, coherent policies, common shared aims (i.e., SDGs)	Agencies dealing with standards, certification and/or regulations
Infrastructure	N/A	Financiers, global funds and foundations	N/A

As far as intermediary actors are concerned, the actors who work at the interface between the private sector and the research environment were also identified.[1] One of these include *AgShare. Today*, a research platform on cassava innovation, linking research institutes with companies funded by the Bill & Melinda Gates foundation and the United Kingdom government. The other intermediary actor identified was *The Association for Strengthening Agricultural Research in Eastern Africa* (ASARECA) who plays host to the Pan African cassava initiative that coordinates cassava initiatives in East African countries including Kenya, Uganda, and Tanzania. Other intermediary actors included *Harvest Plus* and *NextGen Cassava,* the latter being a truly transnational network working on breeding cassava strains that are more adapted to the region by connecting research stakeholders with farming stakeholders and private sector players. Since NGOs were included in the group of intermediary actors, the following stakeholders were identified: *Catholic Relief Services*, *International Fund for Agricultural Development*, the *Syngenta Foundation for Sustainable Agriculture*, *the Rockefeller Foundation* and *Farm Concern International.*

Only two stakeholders were identified under the infrastructure system. These were the international lenders including the World Bank and the African Development Bank who finance various transnational innovative projects along the cassava value chains. When it comes to the political system, several government agencies and institutions seem to collaborate transnationally on cassava innovation. After this initial mapping exercise, we proceeded to interview stakeholders about transnational innovation in the cassava value chain in East Africa.

Regarding the transnational innovation projects, many interviewed stakeholders mentioned the *NextGen Cassava* project which worked with several African institutions to improve cassava varieties in terms of yield and disease resistance, connecting farmers to researchers and the private sector. The project has been implemented in Uganda, Tanzania, Nigeria, and Ghana. Similarly, the *VIRCA* (virus resistant cassava for Africa) project, jointly managed by National Agricultural Research organization in Uganda and the Kenya Agricultural and Livestock Research Organization (KALRO) aims at developing disease resistant cassava breeds but also includes cooperation on issues such as biosafety, intellectual property, and technology. The Cassava Mechanization and Agro-Processing Project (CAMAP), hosted by the African Agricultural Technology Foundation works toward better agricultural practices and agronomics for farmers, strengthening market linkages and boost food security.

The network is active in Eastern Africa, particularly in Uganda, Zambia, and Tanzania. The project C:AVA, implemented by the university of Greenwich, was mentioned as well, which focuses on developing value chains for high quality cassava flour in Uganda, Nigeria, Ghana and Tanzania. Although spearheaded by a British university, the outlook is locally transnational in nature. Another project mentioned was the WAVE Regional Center of Excellence which was established by the Economic Community of West African States (ECOWAS) and serves as a research and network platform on transboundary pathogens including work on cassava with one of its ultimate objectives to increase food security. The Cassava Village Processing Project, implemented by Farm Concern International (FCI) in Kenya, Uganda, and Tanzania with the support of the Alliance for a Green Revolution in Africa (AGRA) was also mentioned.

4 Results

This section thematically discusses results of the study that show the status of transnational collaborations, functions and purpose for transnational collaborations, their benefits, opportunities, and challenges as well as solutions for strengthening transnational collaborations.

4.1 Status of transnational collaborations

Transnational collaborations are important for the growth of bioeconomy in the East Africa region. The experts interviewed argued that having similar resources and challenges, the eastern Africa countries can gain from the regional collaborations which facilitates knowledge exchange and transnational cooperation that empowers disadvantaged countries. After giving interview partners the possibility to mention some transnational innovation projects and networks in the initial open question, the experts were asked to assess the status of transnational cooperation in cassava value cains in East Africa. After giving our definition and providing them with a scale from 0 (no cooperation) to 5 (fully fledged cooperation by many stakeholders, including policy makers, academia, and the private sector)[2] interview partners ranked transnational cooperation at between 3 and 4. This means that the transnational cooperation in East Africa was deemed rather well developed. Some interviewees pointed to the lack of public acceptance for more cross-border

1 According to our taxonomy, we also included NGOs in this category.

2 A full description of the scale can be found in the annex.

integration,[3] a lack of leadership and legitimacy and an asymmetric support from nation states[4] as some reasons why transnational innovation was not as well developed as it could be.

Moreover, modes of collaboration and cooperation across borders would often not be formalized enough[5] and institutional cross-border structures to facilitate more transnational innovation would only slowly be emerging.[6] Discussions with SME managers and their employees on transnational collaborations indicated that transnational innovations are very important in creating new capacity, which can pioneer radical new ideas while testing the limits of markets for various new cassava products. Relationship building and maintenance is however vital for transnational innovations that involve the small and medium enterprises.[7]

SMEs must balance the myriad challenges of assessing potential partners, reaching decisions about what form of collaboration is going to be of advantage, interpreting behavior taking account of cultural differences, resolving the inevitable issues and misunderstandings, and gradually building value together. Most SMEs interviewed indicated that getting the balance right between building trust and maintaining control can be tricky and requires sensitive handling.[8] Therefore, most SMEs take time before they open and share the valuable intellectual property on which a genuine collaboration can be based, hence delaying the partnerships.

4.2 Benefits of transnational collaborations

When asked why stakeholders would pursue transnational innovation, complementarities on each side of the border were mentioned as one reason transnational innovation was pursued by involved actors,[9] thus, confirming arguments made in the literature (see above). In the same vein, most experts mentioned that transnational collaborations facilitate knowledge exchanges across borders.[10] Some experts pointed to the complementarities in knowledge and skills which might exist across borders[11] while others emphasized the pooling of resources and skills.[12] One expert specifically pointed out that these knowledge and innovation complementarities could stimulate innovation activities which would be beneficial to all involved economies.[13] Experts also mentioned that increasing transnational innovation might come about because of the strengthening of personal relations and local networks across borders.[14] Furthermore, experts opined that knowledge creation (and innovation) would always have a cultural and social aspect which might be stimulated and enhanced by cross border exchanges and cooperation.[15]

Similarly, transnational issues such as pest infestation or plant diseases might be best tackled by cooperation across borders[16] and, by pooling resources[17] which was another factor mentioned why transnational innovation and cooperation was deemed beneficial. Indeed, one expert pointed out the costliness of knowledge and skills acquisition in general,[18] a cost that could be lowered by transnational cooperation thus allowing countries and value chains to "stay ahead" in the game of innovation.[19] Another advantage of pursuing a more transnational approach when it comes to cassava innovation mentioned by the experts interviewed would be the co-benefit of increasing trade which would then lead to market creation and expansion and help to match offer and (consumer) demand better.[20] In the same vein, an increase of competition, brought about by market building and integration would allow for specialization of skills and a better division of labor thus making cassava value chains more efficient.[21] Lastly, trust building and capacity building were mentioned as specific co-benefits which would come from a deeper transnational cooperation on cassava issues[22] therefore, leading to the generation of innovative ideas and enhanced capacities to innovate.[23]

4.3 Functions and purpose of transnational innovations

In terms of the principal functions and purposes of transnational innovation systems in cassava value chains, experts were presented with a predefined list of functions of transnational innovation which were drawn from existing literature as shown in Table 2. The options were to *stimulate learning*, *stimulate innovation*, *policy and knowledge transfer*, *technology transfer*, *pooling of resources* and *adding value to existing practices and technologies*. All experts identified different functions as the most important one, while two experts each opined that technology transfer and pooling of resources was the most important function a transnational innovation system could facilitate.[24]

One of the experts interviewed opined that the pooling of resources would also lead to more influence and leverage in negotiations with third parties and argued that lobbying could be done more effectively when resources are pooled.[25] This relates to the argument made by Bößner et al. (2021) in the study on the governance of bioeconomy pathways which argues that regional cooperation, particularly in the Global South, might strengthen the hand of biomass producers there vis-à-vis the international community

3 Stakeholder No 3.
4 Stakeholder No 8.
5 Stakeholder No 1.
6 Stakeholder No 2.
7 Stakeholder No 10, 11, 12.
8 Stakeholder No 11, 14.
9 Stakeholder No 3.
10 Stakeholders No 3, 4, 6, 5.
11 Stakeholders No 5, 4.
12 Stakeholder No 4.
13 Stakeholder No 5.
14 Stakeholder No. 9.
15 Stakeholder No 5.
16 Stakeholder No 8
17 Stakeholder No 4.
18 Stakeholder No 3
19 Stakeholder No 3.
20 Stakeholder No 1.
21 Stakeholder No 4
22 Stakeholders No 5, 6.
23 Stakeholder No 2
24 Stakeholder No 7, 8.
25 Stakeholder No. 9.

TABLE 2 Strength and weakness of TNIS functions.

	Strengths	Weaknesses	Opportunities	Threats
Stimulate learning	Wider scope for Skills acquisition	Lack of common reference frames	Diversified ideas for evolving markets	Cultural barriers
Stimulate innovation	Engages a wider participant pool	Lack of common innovation platforms	Gaining cutting edge or pioneering role at regional level	Competition between countries
Enhance policy and knowledge transfer	Trust building and capacity building	Differences in policy aims and structures	Regional strategy enhanced and improved prospects for implementation	Political barriers to transnational cooperation
Improve technology transfer	Reduced transaction cost for donors and financiers	Lack of technical skills in implementation and maintenance	Make use of sustainable finance mechanisms	Trade barriers
Pool resources	Better use of comparative advantage	Differences in capacities to utilize resources	More leverage in negotiations	Nationalistic tendencies at higher political levels
Add value to existing practices and technologies	Accelerated learning curves	Heterogeneity in practices and technological readiness levels	Expanded demand supports Economies of scale in supply	Differences in consumer preferences

(Bößner et al., 2021). When asked about what part of the value chain of cassava might benefit the most from transnational cooperation, experts pointed to the fact that value addition to cassava remained a challenge because advanced technologies and skills to venture into more lucrative sectors such as bio-based products or biochemicals would be lacking in the region.[26] Similarly, experts pointed out that the awareness of the potential of cassava was lacking among consumers and other stakeholders, not directly implied in the cassava value system.[27] Table 2 provides some analysis across the different functions that were identified and discussed with the interviewees.

4.4 Opportunities for transnational collaborations

In terms of the opportunities for transnational collaborations and the type of actors that would be best suited to drive transnational innovation forward, experts argued that policy makers would be best place to drive TNIS forward by providing the necessary policy framework and the right incentives.[28] Research institutions and NGOs would, in the expert's view, assume enabling functions while policy makers would be the driving force providing for investment in education, skills and science infrastructure as well as facilitating knowledge transfer and by creating a conducive business environment.[29] On the other hand, one stakeholder argued that research institutes would be the driving force but only if they could benefit from royalties or other financial compensation for their research.[30]

Experts also noted that there is need to have a regional support for commercialization of innovation and technology by establishing conducive environments for technology innovation and uptake through innovation centers and funds.[31] This can be done through building upon advances made by the national innovation systems of the East Africa countries while facilitating the identification of areas for innovation where the region has comparative advantage. Already there is a regional center of innovation for cassava in Uganda that is devoted to the development and diffusion of simple, affordable, and efficient technologies that address the basic needs of the community. However, it was noted by the expert that due to the lack of a collective strategy on innovations in the partner states, the innovation centers have limited capacity to respond to opportunities such as the discovery and exploitation of natural resources that require specialized skills or engage in development and innovative activities that require analytical skills.[32]

One other recommendation is to establish a science and technology commission for East Africa, which is needed to facilitate the development of a regional knowledge management database.[33] Experts argued that having a knowledge management database would enhance tracking, collaboration, sharing and dissemination of information and knowledge on various innovations across the cassava and other bioresource value chains within the region.[34] Another opportunity for transnational innovation collaboration is the existence of regional biosciences and bio-business incubation platforms such as the *BioInnovate Africa program* which is essential for facilitating a regional cooperation in the enhancement of innovative biotechnology and bioscience-based solutions for value addition to bioresources including support for centers of excellence in biotechnology, development of biosafety guidelines and supporting development of indigenous knowledge and technologies.[35] According to experts, collaborations with other research organizations and universities is common in the region, where SMEs tend to collaborate with research organizations and universities to develop basic research and experimental development[36] that is oriented to commercialization of products.

Discussions with the SMEs revealed that one of the challenges that limits the transnational collaboration is the difference in priorities of

26 Stakeholder No 8, Stakeholder No 1.
27 Stakeholder No 8.
28 Stakeholder No 3.
29 Stakeholder No 3
30 Stakeholder No 1.
31 Stakeholder No. 12, 14, 13.
32 Stakeholder 14.
33 Stakeholder No 14,
34 Stakeholder 12, 13.
35 Stakeholder 13.
36 Stakeholder No. 10, 11.

partnerships.[37] Most of the research organizations are more oriented to basic explorative research while SMEs want to play a more prominent role in commercialization phase of a technology rather than its experimental and pre-competitive phase compared to research organizations. However, it was noted that despite the difficulties in translating and exploiting research output successfully from research organizations in horizontal pre-competitive collaborations, SMEs are increasingly called to engage in these partnerships to be competitive in an even more complex and uncertain environment.[38]

4.5 Existing institutional, policy and legal framework for transnational collaborations

The need for harmonized policies and strategies was pointed out by most of the experts interviewed as being essential for enhancing effective partnerships and transnational collaboration for the utilization of bioresources.[39] Experts interviewed acknowledged the progress being made in East Africa to harmonize policies and strategies in the region under the East African community to facilitate a regional approach to the development of bioresources such as cassava.[40] Already the East Africa Regional Bioeconomy Strategy has been developed and approved which provides a framework for transnational collaborations needed for developing an innovative and sustainable bioeconomy. It was also mentioned that some policies and strategies that would enhance transnational collaborations have been developed at the regional level.[41] This includes the East African regional policy for intellectual property which encourages technical innovation across the region and promotes the industrial and commercial use of technical inventions and innovations.[42] Another key policy mentioned was the East African Regional science and technology innovation policy which creates an enabling environment for investment in innovations for sustainable regional development and socioeconomic transformations.

In terms of the institutional programs available in east Africa for stimulating transnational innovation, one of the experts[43] mentioned the East African Agricultural Productivity Program (EAAPP) which was conceived as a Regional Agricultural Research for Development initiative between the governments of Ethiopia, Kenya, Tanzania, Uganda. The EAAPP Program enhances regional specialization in agricultural research; collaboration in agriculture training, and technology dissemination; and facilitate increased transfer of agricultural technology, information, and knowledge across national boundaries. The research network called the Association for Strengthening Agricultural Research, and Eastern and Central Africa (ASARECA) was also formed as a sub-regional organization of the National Agricultural Research Systems (NARS) of 11 member countries, namely: Burundi, the Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Madagascar, Rwanda, South Sudan, Sudan, Tanzania, and Uganda. ASARECA brings together scientist from national agricultural research institutions with other stakeholders such as service providers and development-oriented partners to generate, share and promote knowledge and innovation and to solve common challenges. While this organization is still relatively research focused, their collaboration with private sector stakeholders would make them a well-placed institution to drive transnational innovation on cassava.[44] Under its umbrella, a regional center of excellence for cassava was established at Uganda's Namulonge Research Institute. The objective of this center is to strengthen the cooperation on cassava research and appropriate policies for the benefits of all stakeholders. This initiative indeed fits well in our definition of transnational innovation systems by comprising both government and non-government entities. Some concrete results and outputs of the center was establishing market opportunities for cassava-based products including promoting a high-quality cassava fiber mixed with wheat flour which has been used in regional bakeries as a pure wheat flour substitute, and in animal and feedstock (as dried chips) as well as an ingredient for local beer.[45]

When asked what other institutional support transnational innovation in cassava value chains would enjoy, experts mentioned the Strategic Plan 2018–2022 of the East African Science and Technology Commission (EASTECO) which promotes the regional centers of excellence and the exchange and utilization of scientific information as two of its objectives.[46] While this is not specific to cassava, such institutional support could also be useful to stakeholders in cassava value chains. Similarly, experts pointed out that Kenya, Uganda, Rwanda, and Tanzania had established national commissions for science, technology, and innovation which, among other functions, have the role of advising governments on matters of transnational cooperation.[47] However, one expert opined that institutional support was not 'up to the requirements' to spur transnational innovation.[48] *BioInnovate Africa*, a program hosted by International Center of Insect Physiology and Ecology (ICIPE), supports innovation consortia's, including scientists and business actors working collaboratively in a regional context in Eastern Africa to link biological based research ideas, inventions, and technologies to business and the market. The focus is on value addition to agro-produce and other biological resources, including biowaste. *BioInnovate Africa* is in its third phase (2022–2025) supporting a transnational innovation project on using cassava waste to produce bio-packaging material for the East African market.

4.6 Challenges of transnational innovation

Despite those policies, frameworks and support initiatives mentioned in the previous section, experts still identified the insufficient institutional support as a major challenge to transnational innovation in Eastern African cassava value chains. This includes institutional structures for linking various innovation actors such as

37 Stakeholder No 12.
38 Stakeholder 13, 15.
39 Stakeholder No 10, 11, 14.
40 Stakeholder No 13.
41 Stakeholder No. 15, 16.
42 Stakeholder No. 15.
43 Stakeholder No 3.
44 Stakeholder No 3.
45 Stakeholder No 3.
46 Stakeholder No 3.
47 Stakeholder No 3.
48 Stakeholder No 1.

incubating facilities. Moreover, many challenges identified in the literature were, independently, mentioned by interviewed experts such as the lack of common identity and the 'cultural distance' which might hinder transnational innovation.[49] According to experts this was not only from an end-user or worker perspective but also from an organizational perspective since diverging work cultures would hinder 'harmonious' cooperation between various innovation actors, such as academic and private sector actors.[50]

Similarly, different legal frameworks across borders and the lack of harmonization between these frameworks were identified as a challenge,[51] as were the lack of harmonization when it comes to product standards.[52] Moreover, several experts argued that cross border and transnational cooperation would simply not be high on the policy agenda and the strategies of countries in East Africa.[53] Missing linkages between institutions was mentioned as well,[54] pointing to the need to formalize cooperation also on an institutional level. Moreover, dissimilar legal and administrative conditions and steps to take if one wanted to collaborate more closely across borders were identified as challenges.[55] In the same vein, diverging political priorities and the oftentimes difficult and unstable political situation in the different countries were identified as another challenge. This could also lead to stakeholders losing interest in transnational cooperation, depending on the changes in the political environment.[56] Other experts pointed out the importance of 'coordination mechanisms' (or 'intermediary actors', 'bridging institutions or business incubators as they have been called in the literature) which would bring together and coordinate the sometimes-diverging responsibilities and needs of public and private sector entities.[57]

However, the most important challenges identified many times by several experts was the lack of financial resources to further develop cross-border collaboration.[58] Although the complexity of today's business environment requires collaborative efforts by multiple actors, transnational innovation collaborations among the SMEs are not properly established in the East Africa region. Discussions with business leaders and entrepreneurs who have experience with these types of collaborations along cassava value chains indicated that there are several challenges that small and medium enterprises in the region experience when collaborating which are driven by technology type, sector practices and capital intensity of the collaboration.[59] It was noted that in intellectual property intensive industries where the purpose of the partnership is actively developing and testing new products, negotiating intellectual property agreements, and ensuring all parties are adequately protected is a major challenge in the region and even if most countries in East Africa have national intellectual property regulations in place IP frameworks and IP policies at institutional level have not been well developed.[60]

Discussions further revealed that successful transnational innovations with SMEs have a higher chance of success when both parties have clear, communicable objectives[61] Establishing clear objectives requires carefully scoping the innovation area.[62] According to a representative of the SME interviewed, without this clarity, there is a far higher risk of failure to find a suitable partner, misalignment between parties in the event of a partnership, and inadequate capacity and experience to enter into partnership agreements.[63,64,65] Unfortunately, small enterprises lack the financial resources to 'push' their images and messages effectively like the large companies do portraying positive images and sending appropriate messages to the customers in media resulting into a capture of a large percentage of the market share and collaborations. Another challenge is the underestimation of some SMEs' capacity and efforts due to lack of trust.[66] In this regard, it is important that projects leverage mechanisms that increase trust between partners. Most of the time, projects are structured and coordinated by following logics that are more suitable for large organizations than for SMEs, with the result that SMEs tend to occupy weaker network positions and to depend on partners' strategies instead of having control on the direction of their open innovation efforts.

4.7 Strengthening transnational innovations

According to the interviewed experts, transnational collaboration and partnerships that contribute to the development of new models, innovations, policies, and investments in the cassava value chain initiatives are vital for a sustainable bioeconomy in East Africa.[67] The most important aspects for strengthening transnational innovations in east Africa identified by the experts could be summarized under *appropriate governance and policy* and *appropriate funding mechanisms*. Stronger political commitment, institutional support and a demand-driven approach for transnational cooperation would help cassava innovation.[68] Moreover, governments should encourage private sector investment in cassava value chains and establish credit lines to enable private suppliers to deliver in bulk and on time for further processing.[69] This is in line with another argument that functioning supply chains were key to successful transnational innovation.[70]

Several experts argued for a market driven approach, where governments facilitate not only market building but also the necessary

49 Stakeholder No 3.
50 Stakeholder No 7.
51 Stakeholders No 1, 2
52 Stakeholder No 1.
53 Stakeholders No 3, 8.
54 Stakeholder No 6.
55 Stakeholder No 2
56 Stakeholder No 2.
57 Stakeholder No 5
58 Stakeholders No 2, 4, 5, 6
59 Stakeholder No. 12, 14.
60 Stakeholder No. 12.
61 Stakeholder No. 14.
62 Stakeholder No. 14, 15.
63 Stakeholder No. 14, 11.
64 Stakeholder 14.
65 Stakeholder No. 14, 10, 17.
66 Stakeholder No. 12, 15.
67 Stakeholder No. 15, 13, 10.
68 Stakeholder No 2.
69 Stakeholder No 3
70 Stakeholder No 3.

private public partnerships for engagement.[71] It was also suggested that joint networking actions at regional level, as well as promoting the collaboration to support science and innovation, entrepreneurship, and access to finance for regional cassava value chain development would be key in ensuring effective collaborations. There is also the need to support the synergies between Eastern Africa countries and key actors working on the advancement of cassava value chain and developing policies that seek to strengthen transnational innovations either at institutional, program and government levels. It was further suggested that, to enhance technical and entrepreneurial skills for value addition, there is need for a harmonized regional approach to create structures and capacities for enhancing innovation and deployment of technologies and the know-how for value addition to primary produce and biowaste in the region. This according to the experts interviewed would create a basis for regional collaboration, knowledge sharing and capacity building as well as promote regional markets for various cassava products.

To enhance the transnational innovation collaboration between academia with SMEs along the cassava value chain, experts recommended that SMEs need to assess and acknowledge the value of a potential collaboration at a strategic level within the firm and defining objectives to ensure executive commitment at multiple levels.[72] This can be done by jointly and transparently articulating the intent and business case for collaboration both internally and externally, defining the value and resources to be contributed by and brought to partners. It is also important for the SMEs to understand the constraints and consider the costs and benefits of partnering from the perspective of potential partners, to ensure that collaboration objectives and processes are aligned for maximum mutual gain.

5 Discussion

Transnational collaborations are expected to bring about a wide range of benefits and to encounter various barriers. The findings here show that transnational collaborations are important for building capacities, provide organizational support and lend the opportunities to integrate issues of international relevance in innovations along various bioeconomy value chains. Transnational collaborations according to Caniglia et al. (2017) are important in accelerating innovations and learning. Similarly, most partnerships and collaborations identified in this survey show that organizations and institutions that have collaborated transnationally along the cassava value chain do so to generate, compare, and integrate knowledge from different contexts as well as accelerate innovations within and across value chains. Because of the highly competitive marketplace, transnational collaborations are key for triggering innovation as all the collaborating partners brings their unique set of skills, knowledge, approaches, experiences, and ideas that give way to new products through the combination of unique perspectives (Bezama et al., 2019). As shown with our findings, through collaborations, businesses/institutions/organizations can bring their resources together to cut costs and mutually benefit from innovation.

The multi-institutional findings presented here show that the East Africa region has a strong bioresource production base but lacks the requisite structures, technologies, venture capital and skills for bioprocessing and value addition. Transnational collaborations are therefore important for developing and deploy a diverse range of new bioproducts with new functionalities. Quite a lot of development has occurred, but the bottle neck is scaling up and commercializing.

The private sector and the SMEs in the region, with some exceptions, invest very little in their own R&D or in adopting and deploying promising new technologies or innovations (Liavoga et al., 2016). The public R&D institutions in the East Africa region therefore play a strategic role in adapting knowledge, innovations, and technologies suitable for improving crop production and value chains (Virgin et al., 2016). The public sector is however not very effective in upscaling and commercializing innovations, new technologies or products and hence the need for linking with local SMEs that are more able to exploit market opportunities and engage in market creation. To strengthen innovation and transnational innovation around cassava production and value chains there is a need for public R&D institutions able to engage in innovation in partnership with the private sector. This would require public R&D to ensure that they have a minimum capacity in areas such as technology transfer to link with the private sector. The African SMEs sector is however seldom effectively engaged with the public R&D sector to disseminate and deploy technologies, resulting in those innovations to large extent remains undeveloped and stays on the shelf (Virgin et al., 2016). Consequently, also in the case of TNIS it is critical to support links between the public sector and market actors. But linking the public sector with the market actors is often not enough, there is also a need for mechanisms to help incubate businesses to ensure that all actors in the innovation system are properly linked and supported so they can play complementary roles. Thus, there may be a need to assist TNIS innovation actors with things like business plan development, technology, IP, and market assessments. This can be done through institutional structures such as incubators, science parks and various collaborations platforms such as the *BioInnovate Africa* program presented above.

Although the complexity of today's business environment requires collaborative efforts by multiple actors (Bezama et al., 2019), the findings show transnational innovation collaborations are not well established with the small and medium enterprises in the East Africa region. The several challenges that small and medium enterprises in the region experience when collaborating is driven by technology type, sector practices and capital intensity of the collaboration (Nyamrunda and Freeman, 2021). This is especially in the intellectual property intensive industries where the purpose of the partnership is actively developing and testing new products. Here, negotiating and agreeing on intellectual property agreements is key, ensuring all parties are adequately protected and the sharing of potential benefits are agreed upon. Such negotiations require clear rules regarding who owns what, capital flows and timing which would occur within a proper IP framework to operationalize national and institutional IP policies available in the region. These findings draw attention to the often unnoticed, but vital, role that institutional and policy frameworks play in initiating as well as supporting transnational research endeavors that address issues of current and future global concern.

71 Stakeholder No 8.

72 Stakeholder No. 12, 13.

The transnational collaborations are inspired by growing understanding that, by itself, no amount of research in any one country, nor any single institution, can fully comprehend, let alone resolve, the multiple and increasingly complex global problems that confront humanity. The harmonization of policies and strategies in the East Africa region and the vibrant institutions will therefore play a key role in advancing the transnational innovations for bioeconomy development.

The question we turn to now is the extent to which transnational innovation systems support–or have the potential to support–advancement of a transformative bioeconomy, using the case of the cassava bio-resource base in eastern Africa. Considering first the existing TNIS that were identified during interviews, we can place this question within the context of the core characteristics of the bioeconomy: cross-cutting, innovative and value-adding. It should be noted that we made no attempt to evaluate the effectiveness of these programs or projects but rather only the intended aims are considered using a cross-sectoral bioeconomy perspective. Furthermore, while the projects mentioned reflects consideration from the bioeconomy lens, the initiatives may nevertheless be quite important and effective regardless of whether they possess the wider transformative aims of bioeconomy. The C:AVA project, for example, appears to aim for significant added value, by promoting multiple products and a diversity of value chains. Several initiatives (VIRCA, CAMAP and WAVE Cre) are primarily sector-oriented in that they aim for improved agricultural productivity. Note also that although the focus in this paper is on East Africa, we have included examples from other regions (e.g., WAVE is focused in Central and western Africa) due to their bioeconomy relevance and since cassava is important across sub-Saharan Africa.

Programs or initiatives specific to cassava have been the focus here, but there are also other programs or initiatives using the bioeconomy perspective that might more appropriately address multiple crops or bio-resource streams (e.g., agricultural wastes), multiple applications and multiple markets. The Bio-innovate Africa program, for example, is one such major program focusing on bioscience-based value addition to primary agricultural produce, including casava and conversion of biowaste to useful products and aims for transnational innovation in eastern Africa. Since cassava is in some ways a foundational element of the agricultural bio-resource base in the global South, this deep dive for one crop can also offer some broader development perspectives across multiple SDGs, i.e., by linking food security with economic diversification, social investments, and climate resilience.

In considering the future potential for TNIS and again emphasizing the insights from interviewees for cassava, we can employ as an axis of analysis the different functions identified in the literature, namely: to stimulate learning; stimulate innovation; enhance policy & knowledge transfer; improve technology transfer; pool resources; and add value to existing practices and technologies. Our question is then to consider the advantages and disadvantages (or strengths and weaknesses) of TNIS across these functions, in terms of the extent to which–and the means for which–they can advance the bioeconomy relative to national innovation systems.

Another question of interest is the role of the key actors themselves in transnational innovation systems. Although the interviewees themselves were largely experts from academia, government and think tanks, their answers in combination with the literature review and internet searches suggest a simple characterization that can be useful, namely that actors serve as drivers, enablers, or regulators of transnational innovation. The drivers are those that initiate innovative solutions in the form of new products, processes, management systems, or applications (Kardung et al., 2021). The enablers are those who provide the means for innovation, namely financing, technology, and capacity (Salvador et al., 2022). The regulators are those concerned with economic and environmental risks and/or socio-economic or environmental impacts.

The information obtained in this scoping exercise is insufficient to distinguish which actors are both willing and able (have the capacity and institutional support) to engage transnationally as opposed to focusing on their domestic bio-resources and associated markets and policies. We had difficulty identifying SMEs that worked internationally although this is likely due to smaller companies in most parts of sub-Saharan Africa not necessarily having web pages and/or significant internet presence that would allow us to identify them without a deeper investigation.

More generally, in the East African or southern African context, private enterprises engaged in innovative bio-based industries are rather limited outside of South Africa, although there are project developers working with "industrial" crops such as sugarcane, cotton and tobacco. Due to its special value and efficiency in providing low-cost calories, cassava still largely retains the status of being a crop mainly for smallholder farmers, even though it has significant potential as an industrial crop and is pursued as such on a large scale in other parts of the world (such as Thailand, Brazil). Consequently, a specific question to be posed for future research following up on this paper is how transnational innovation systems can contribute to the process of exploiting cassava as an industrial crop and thereby harnessing its potential for a modern and productive bioeconomy in the region.

6 Conclusion

The study highlights the purpose, challenges, and opportunities for transnational innovation systems along the cassava value chain in East Africa. Appropriate governance, institutional structures, collaboration platforms, enabling policies and appropriate funding mechanisms are the key aspects identified for strengthening transnational innovations in East Africa. Therefore, a stronger political commitment, institutional support for promoting partnerships and a demand-driven approach for transnational cooperation would stimulate transnational cassava innovation in East Africa. Partnerships, networks, and collaborative spaces that offer opportunities for synergy and complementarity are vital for building effective transnational innovation systems to enhance the sustainability of production, bioprocessing, and value addition of biobased cassava products. Effective transnational innovation systems are built upon mutual trust and participation by all collaborating parties in project design, decision making, resource support, management, evaluation, and benefit taking. From project design through implementation, evaluation, and dissemination, developing trust and demonstrating competence in interacting with counterparts of diverse nationalities and across specialization boundaries are key for advancing transnational innovation systems to support the transformation to a modern bioeconomy.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary materials, further inquiries can be directed to the corresponding author/s.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided written informed consent to participate in this study.

Author contributions

AL, SB, FJ, IV, MT, and PO contributed to conception and design of the study. AL organized the database. AL and SB performed the statistical analysis. SB, FJ, and AL wrote the first draft of the manuscript. AL, SB, FJ, MT, PO, and IV wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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