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ORIGINAL ARTICLE

# Value chain climate resilience and adaptive capacity in micro, small and medium agribusiness in Jamaica: a network approach

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**Abstract**

In advancing relational understandings of resilience and adaptive capacity, this paper explores how business networks influence value chain climate resilience and the ability of small businesses to adapt to climate change. The relationship between value chain network attributes (i.e. connectivity and an actor's centrality) and indicators of value chain resilience (e.g. information sharing, flexibility and redundancy) is investigated through the analysis of qualitative data derived from field interviews and from the quantitative assessment of network metrics characterising information, financial and material flows of three agricultural value chains in Jamaica. The study illustrates how network analysis offers a systematic approach for understanding value chain resilience and the adaptive capacity of micro, small and medium enterprises (MSMEs), and supports strategy development in business value chains. The study concludes that mixed-methods networked approaches provide valid methods for exploring a relational understanding of climate resilience in value chains, opening up new research opportunities for scholars interested in private sector climate adaptation.

**Keywords** MSMEs · Network analysis · Climate resilience · Value chains · Caribbean · Jamaica

## Introduction

Micro, small and medium enterprises (MSMEs) dominate the landscape in most economies. They represent more than 95% of registered businesses worldwide and contribute significantly to national income (over 35%) and employment (near to 50%) in the developing world (World Bank 2017). Additionally, they are a key foundation for economic growth and a source of flexibility, dynamism and innovation in times of environmental turbulence (Thoo et al. 2017).

MSMEs are most commonly defined according to number of their employees and total turnover, but this changes across countries. Despite the benefits they accrue to society and the economy, MSMEs are exposed to contextual forces that hinder their performance and survival. These include low pools of internal resources, insufficient access to finance and information, high dependence on external business and policy cycles, and unfavourable power struggles (Crick et al. 2018a, b; Smith and Deslandes 2014; Kuruppu et al. 2013).

These forces make MSMEs particularly vulnerable to the effects of climate change. The levels of climate vulnerability can, however, differ significantly between MSMEs, depending on their location, their sector and size. The business-network operational environment in which MSMEs are embedded also plays an important role in mediating vulnerability, affecting MSMEs' exposure to indirect risks and their levels of adaptive capacity. Studies applying network-based simulations, normal accident theory and agent-based models have started to show how network structures may affect businesses' exposure to risk and the dynamics of risk propagation across value chains (Ledwoch et al. 2018; Scheibe and Blackhurst 2018; Lim-Camacho et al. 2017; Han and Shin 2016). Similarly, more qualitative assessments illustrate the contribution of network environments to the adaptive capacity of actors. Agricultural MSMEs with access to formal and informal support networks (e.g. cooperatives) have been found to display stronger adaptive capacity than those without (Crick et al. 2018a, b; FAO 2012). Similarly, the adaptive capacity of

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MSMEs is reported to be influenced by the adaptive capacity of the organisations that support them through the provision, for example, of education and training, finance and regulation (Kuruppu et al. 2013).

Although it is clear that the networks in which small businesses are embedded can affect their adaptive capacity, our current understanding of this dimension of vulnerability remains highly fragmented and lacking systemic approaches to understand these relationships (Halkos et al. 2018; Kuruppu et al. 2013; Wedawatta et al. 2010). This poses a problem for decision makers in developing countries when they try to understand and influence the climate resilience of sectors where MSMEs dominate, such as in agriculture.

This study explores how business-network environments influence MSMEs' adaptive capacity by formulating a mixed-methods approach that allows an investigation of the relationships between network structure and resilience outcomes in agricultural value chains. The method is here used to examine the interaction between these two variables in mediating the adaptive capacity of individual businesses. Focus is placed on properties characterising resilience in whole value chains (such as information sharing, robustness and redundancy) and on network structural attributes influencing network resilience (such as connectivity and actor's centrality). This emphasis brings broader network interdependencies to the fore, in contrast to established approaches emphasising the role of dyadic relationships (i.e. business-to-business interactions) or focused on the resilience of ego-networks (i.e. network of relationships around a specific firm). Additionally, network analysis is here applied to examine structural attributes within three selected agricultural value chain networks, and to relate network attributes to specific adaptation constraints affecting MSMEs. In doing so, the study proposes an operational definition of resilience, as a property of value chain networks that allows actors within the network to build their adaptive capacity; it also operationalises network theory for the analysis of value chain climate resilience, in alignment with a specific management problem (i.e. MSMEs' lack of adaptive capacity).

The paper is ordered as follows. The "Theoretical framework" section proposes a conceptual framework for exploring the relationship between value chain network structure, resilience and adaptive capacity, and provides the main conceptual considerations and definitions of the paper. In particular, the section explores how two key network structural attributes (i.e. connectivity and actor's centrality) can influence properties attributed to resilient value chains (in particular their effects on information sharing, flexibility and redundancy). The "Methodology" section outlines the methodology used to examine the relationship between network structures, resilience properties and adaptive capacity, applied through a comparative analysis of network typologies in three agricultural value chains in Jamaica (namely in the cassava, tilapia and ornamental fish value chains). The "Results" section presents the main results from the study and explores the implications for decision-makers stemming from this analysis, offering recommendations on possible intervention points for building enabling conditions for MSMEs' adaptation. Finally, the "Conclusions" section offers concluding remarks and points to future research areas that could build on this networked approach.

## Theoretical framework

This section explores how value chain network structures influence resilience to climate change and MSMEs adaptive capacity. As shown in Fig. 1, value chains comprise a range of activities, resource flows and actors commonly linked together. Their interaction enables value generation through the delivery of specific products and services (Anderson et al. 1994; Borgatti and Halgin 2011; Håkansson and Snehota 2006). The configuration of network structures varies from value chain to value chain and is characterised through the measurement of network attributes (or metrics), such as

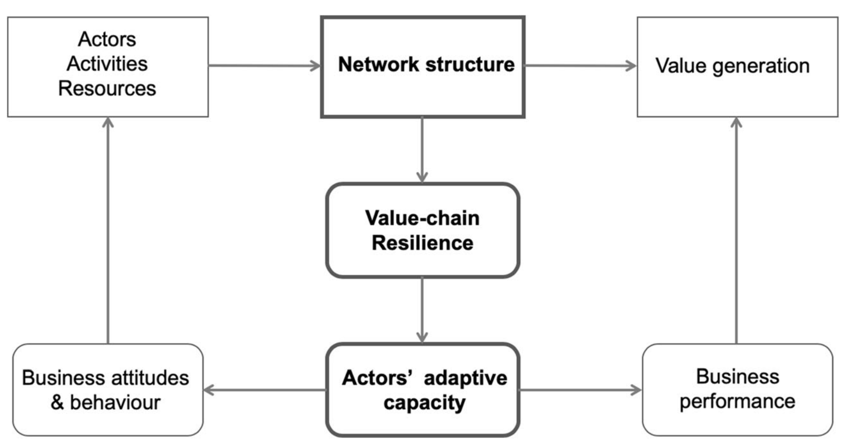


**Fig. 1** Conceptual illustration of the relationship between network structure, value chain resilience and actors' adaptive capacity. In bold: the main components addressed in this paper

network connectivity and actors' centrality (further defined and explored in the "Network attributes influencing value chain resilience" section). Here, we argue that these network structures influence the manifestation of resilient properties (such as information sharing, flexibility and redundancy), and that the presence or absence of these properties infers on the adaptive capacity of individual actors along the chain. In turn, the capacity of actors to adapt, mediated through the levels of resilience in the value chain, influences business performance and businesses' adaptive behaviour.

## Value chains as networks

Value chains comprise a series of actors tied together by flows of resources and shared or linked activities. These flows can be classified as primary (i.e. those that satisfy customer needs (or up/down-stream partner) and that are generally expressed through material and financial flows), and secondary (i.e. those that help control and develop the value of a business and are tied to flows of information and regulation) (OECD 2008). Accordingly, actors can be considered as primary or secondary according to the nature of the flows that ties them together.

Value chains have been primarily conceived as linear sequences of activities, in resonance with manufacturing and retail views of modernist industrial production. Known also as supply chains, these representations of production systems generally overlooked the importance of secondary actors and flows (OECD 2008). Progressively, value chains have been reconceptualised as configurations or networks of interactions, accounting for secondary actors and flows, and acknowledging the role of bi-directional resource exchanges (such as information flowing both ways between customer and producer), which strongly influence the competitive advantage of actors within a given value chain (Porter 1985).

Linear understandings of supply chain relationships—originating in strategy management studies—have understood value creation as something that accrues only at the firm level. Accordingly, analytical emphasis has been on the role of dyadic relationships (i.e. a one-to-one relationship between two actors) and on the structure of ego-networks (i.e. the relationships and activities centred around a particular firm) (Anderson et al. 1994) (see Fig. 2). This assumes that firms position themselves within their network, increasing their 'bargaining power'[1]; but provides little information on the characteristics of the broader value chain network, such as the number of actors involved and the level of connectivity between them. To gain this perspective, all dyadic and ego networks within a value chain can be integrated to produce a spider-web view of the network (see Fig. 2). Rather than representing the interactions and interdependencies of importance to any single focal firm, this perspective offers a representation of the entire network; it thus extends the boundaries of analysis to include all interactions and exchanges that occur within a value chain.

For the purpose of understanding value chain resilience properties and how they influence a firm's adaptive capacity, both spider and dyadic views of the value chain are useful. On the one hand, the spider-networked view creates a formal understanding of the structure of value chain interactions (e.g. how many actors, what resources flow between them, flow pathways, connectivity, etc.), without focusing on any one given actor or relationship. On the other hand, the analysis of dyadic relationships helps to better understand the processes that have led to the formation of certain relationship, their purpose, meaning and strength (Canevari-Luzardo 2019; Canevari-Luzardo et al. 2019). The analysis of ego-networks has been left out of this study as ego-network framings are less useful when faced with the challenge of framing resilient strategies at the value chain level. Additionally, resilience strategies framed around the interests of any one specific actor may redistribute vulnerabilities along the value chain and thus result in maladaptation. Dyadic and spider-web views therefore offer two levels of analysis that can better inform MSME-focused management strategies. This paper focuses primarily on the spider-web view, whilst the analysis is complemented in Canevari-Luzardo (2019) at the dyadic level.

As networks are dynamic and actors can be embedded in multiple network domains simultaneously (Huggins 2000; Mizruchi and Galaskiewicz 1994), it can prove challenging to determine network boundaries. Some scholars have started to draw them according to a management problem (Bodin et al. 2017; Bohan 2016; Dee et al. 2017). Here, the boundaries were more easily bounded by the small size of the value chains explored, so that a spider-web view of the network could be created through mapping and linking the ego-networks of all actors identified and interviewed, as it will be further explained in the "Methodology" section. For larger supply chains, the identification of network boundaries can prove more challenging, but can be more easily defined around a specific management problem.

## Value chain resilience: definition and properties

Based on a review of five sources collecting 60 definitions of value chain resilience (Hohenstein et al. 2015; Kamalahmadi and Parast 2016; Pires Ribeiro and Barbosa-Povoa 2018), strategy management studies seem to most commonly define resilience as the ability of a value chain to collectively prepare for, respond to and recover from a disturbance (Jüttner and Maklan 2011; Ponomarov and Holcomb 2009; Datta et al. 2007), as well as its capacity to return to its original state

[1] A company's bargaining position is a measure of its competence and fitness. This important property explains why new businesses may outperform well-established ones, despite being new to a network and hence lacking the larger number of relationships and linkages established by older firms.

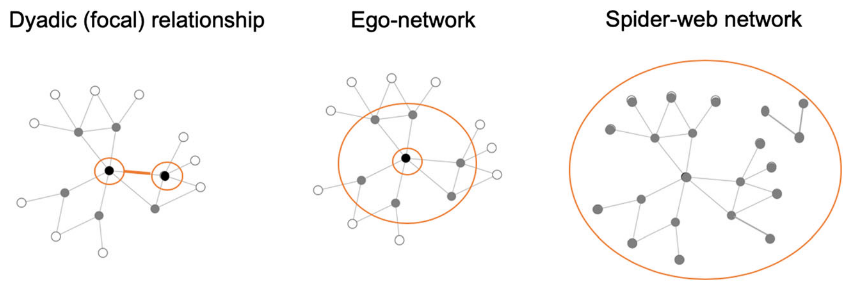


**Fig. 2** From a focal analysis on dyadic business relationships and ego-networks to the assessment of full value chain-network structures

(Brandon-Jones et al. 2014; Mandal 2012; Yang and Yang 2010), or to move to a new more desirable state that confers it with new stability (Elleuch et al. 2016; Hohenstein et al. 2015; Christopher and Peck 2004; Spiegler et al. 2016; Soni and Jain 2011).

Existing framings for resilience strategy development have been critiqued in climate studies for their 'normative notions of what resilience ought to look like' (Rhiney et al. 2018, p.2); as well as for their tendency to direct attention away from the persisting and underlying structural inequities driving climate vulnerability (Rhiney et al. 2018; Pelling 2011). In this study, value chain climate resilience is framed as a co-constituted relational and emergent property of networks that enables value chains (and their actors) to be transformative, and to adjust to changing environmental conditions. As such, focus is placed on the ability of a resilient system to enhance the adaptive capacity of its actors and to develop its own capacity (which is more than the sum of its parts) to effectively prepare for, respond to and recover from shocks. The approach thus aligns with the general intent exposed before, of finding levels of analysis that can better inform MSME-focused management strategies.

Value chain resilience understood in this way is an inter-organisational property and a network-wide concept, naturally dependent on collaboration (Boruff and Cutter 2007; Christopher and Peck 2004; Jüttner and Maklan 2011; Soni and Jain 2011). Collaboration, in turn, depends on trust, a key ingredient in the development of long-lasting cooperation between firms (Huggins 2000) and a founding element of collective action (Ostrom 2005). Trust arises from the social context in which a business is embedded, and out of overlapping personal and economic relationships (Bradach and Eccles 1991, cited in Huggins 2000). Collaboration is also enabled through information and knowledge sharing, which relies on the levels of trust between value chain actors, and their willingness to share sensitive and risk-related information (Soni and Jain 2011). Together, trust and information-sharing help to build collaborative value chain risk-management responses, improving the anticipation, response, recovery and growth stages that accompany an external disturbance.

In addition to collaboration, value chains must be also agile and therefore able to see and understand activities and resources present at both ends of the value chain, and able to respond quickly to change by adapting their initial configurations (Wieland and Wallenburg 2013). Similarly, they must have the ability to re-engineer themselves by being both flexible and redundant, and share basic elements of the same risk-management culture (e.g. a common language, a common set of goals and an understanding of threats) (Kamalahmadi and Parast 2016).

## Network attributes influencing value chain resilience

As argued in the "Value chains as networks" section, value chains are network configurations, linking resources, activities and actors that collaborate in the development of values and services. Broadly speaking, a network consists of a set of nodes connected via a set of links, where linkages between the nodes represent specific types of relationships (Borgatti and Halgin 2011). In a value chain network, linkages between actors can represent different types of exchanges, such as material, information and financial resource flows.

Two network structural attributes are here chosen to explore how network structures influence value chain climate resilience, namely connectivity and centrality. A similar application of these two metrics to the study of socio-ecological systems provided by Janssen et al. (2006) has shown that '… by using just connectivity and centrality we can capture the essential functional implications for the resilience of the structure of a given social-ecological network' (p.4). In this paper, we use the same approach to explore the effects of these network attributes on value chain climate resilience.

### Connectivity

Connectivity is most commonly measured by *density* (i.e. the number of links divided by the maximum possible number of links). The higher the density of a network, the more connections between the nodes, and thus the more pathways through which resources can travel across the network (Newman 2010). Density can have both positive and negative outcomes. For example, highly dense networks exhibit faster transferals of information and rules, which can help in the promotion of common norms and values to catalyse collective action (Alexander et al. 2015; Bodin and Crona 2009). In contrast, they can also be more vulnerable to risk propagation and cascading impacts (Craighead et al. 2007). In this study, we explore density in combination with two other connectivity metrics: average degree (i.e. the number of connections a node has with other nodes) and average length path (i.e. the number of steps in the shortest path between any two nodes).

Another way to represent connectivity is through the network's *modularity*. Network modularity helps to define the set of sub-groups within a network. It can also be examined through the modularity degree (i.e. the level of partitioning) and the average clustering coefficient (i.e. the ratio between the number of links in the immediate neighbourhood of an actor in relation to the total possible number of links) (Wyss et al. 2015). The formation and the maintenance of sub-groups plays a role in value chain resilience, as these can positively or negatively affect group dynamics. On the one hand, actors within a sub-group tend to develop higher levels of trust between them and display higher generation and transfer of tacit knowledge deemed important for collective governance (Bodin and Crona 2009) and for joint problem solving (Uzzi 1997). However, very high levels of modularity can challenge joint actions aimed at governing a common natural resource or a common management problem, due to the risk of 'us vs. them' attitudes among actors in networks, which can reduce a group's effectiveness in collective action (Wyss et al. 2015; Oh et al. 2004 in Bodin and Crona 2009; Borgatti and Foster 2003; Granovetter 1973).

### Centrality

Centrality is a measure of the relative position of an actor in relation to its network and also of its relative importance and ability to leverage resources from other organisations (Huggins 2000; Murdoch 1997; Granovetter 1973). This metric describes how important a node is with respect to its nearest neighbours and can be examined in terms of different types of centrality measures[2] (Newman 2010). In the context of this project, we decided to explore how actors' out-degree centrality may help reveal the power and social influence of keynote actors (Norberg and Cumming 2008). As noted by Degenne and Forsé (1999, in Norberg and Cumming 2008) 'numerous studies in social science agree that power is bound up with centrality, although the connection is not straightforward' (p.98). As noted by (Alexander et al. 2015), 'social influence serves as important entry points to understand the potential for the introduction and adoption of new norms' (p. 218). Whilst high levels of centrality may allow for better coordination of activities and responses to external stressors, it may result in lower distribution of key resources, reduce the diversity and robustness of network functions, and generate perceptions of management processes as undemocratic or unfair (Janssen et al. 2006). Contrastingly, low levels of centrality may be perceived as fairer and more participatory and may increase networks' robustness to the removal of nodes, yet it may also reflect lack of control and low efficiency in the response and management of external stressors (Janssen et al. 2006).

## Methodology

### Rationale

This study used a mixed-methods approach for the collection and analysis of relational data. Whilst quantitative analysis allows for the exploration of the 'relational form' of the networks, qualitative enquiries are necessary to understand the 'relational content' of network interactions: the quality and meaning of ties for those involved (Edwards 2010). The application of network analysis is here undertaken through a comparative case-study analysis of network factors influencing climate-change resilience and MSMEs' adaptive capacity in three agricultural value chains in Jamaica.

In this study, network analysis is introduced as a tool that can help to understand factors constraining MSMEs' adaptive capacity for a number of reasons. First, it provides an easy platform to map all actors and resource flows in a production system. This is important because it helps to examine the role of small businesses in larger value chain networks and helps interpreting resource-access constraints affecting the adaptive capacity of these actors. Additionally, by focusing on the role of network interactions and interdependencies, network analysis helps to reframe adaptive capacity in the context of resources and capabilities that may span beyond traditional organisational boundaries. This shift in focus can generate a different variety of climate-resilience strategies, focused on the adequate management of business relations and on the adequate flow of resources between actors.

### Case study selection

Climate change has a significant impact in the agricultural sector of Jamaica (Selvaraju et al. 2013). Recent events, such as the drought of 2014–2015—which affected over 18,000 farmers and resulted in economic losses of US$7.7 million (Government of Jamaica, 2015)—demonstrate the vulnerability of the sector and the challenges of formulating adequate management responses (Rhiney et al. 2018).

[2] (i) Degree centrality (i.e. the number of connections one actor has compared to the number of nodes in a network); (ii) closeness centrality (how close an actor is to other nodes in the network); (iii) betweenness centrality (which measures the number of pathways that run through a specific node); (iv) keystone centrality (i.e. a node that has a stronger effect on the overall network); and (v) eigenvector centrality (where high-scoring nodes contribute more to the score of the node in question than equal connections to low-scoring nodes). In directed networks, degree centrality can be further divided into in-degree and out-degree centrality: the first one refers to the number of links a node receives whilst the second measures the number of relations and flows from one node to its wider network.

The Caribbean region is further expected to experience erratic rainfall, higher temperatures, stronger droughts and greater climate variability, all of which will affect agricultural productivity (Mycoo 2018; Rhiney et al. 2018; Thomas et al. 2018). The impact on agriculture in Jamaica and within the broader region is projected to be substantial under a 1.5 °C scenario, and likely to exacerbate under 2 °C warming (Thomas and Benjamin 2018). However, current adaptation strategies within the agriculture sector have remained highly focal and fragmented; hence, innovative and value chain-inclusive approaches that may support the coordinated transformation across entire agricultural value chain systems are being called upon (Rhiney et al. 2018). In using a whole value chain network approach, this study therefore complements other adaptation agricultural studies that have solely focused on climate change impacts and risk perceptions at the farm level (including Ali and Erenstein 2017; Elum et al. 2017; Tripathi and Mishra 2017; Knudson 2015; Rhiney et al. 2015)).

Additionally, the three value chains selected are exposed to similar climate challenges (in particular droughts) and share similar economic constraints (such as high costs of production, lack of economies of scale and difficult access to markets). They have nonetheless very different network structures. This scenario allows us to examine how network structures influence value chain resilience and actors' adaptive capacity, when other external conditions remain largely constant.

All three value chains are perceived as under-utilised (in terms of overall output and employment rates). This allowed us to explore the operationalisation of network theory under a specific management context: how to help develop these value chains in a way that they are more climate-resilient and confer more adaptive capacity to small and medium enterprises. One he benefits of selecting Jamaica for the case studies was that it constrained the value chain to a manageable scale, allowing to make relevant recommendations about the industries.

### The cassava value chains

In Jamaica, cassava is traditionally used for the production of bammies (a form of flat bread). Its value chain is primarily composed of small-scale farmers and cooperatives, small cottage processors and small to medium processors. Additionally, cassava is being used as substitute of barley in beer and explored as substitute of wheat in bread. In both cases, the value chains are composed of farming cooperatives and large processors. For the purpose of this study, both these typologies of cassava value chain have been mapped.

### The tilapia fish value chain

In Jamaica, tilapia is farmed in extensive or semi-intensive systems and predominantly sold either fresh or live by vendors and retailers in the local market. The majority of fish farms are small (1 to 5 ac. of ponds) to medium (6–20 ac.) scale. In addition, there are two major processors of seafood products and one large producer of tilapia that have started processing tilapia to sell value-added products (primarily seasoned fillets) in the local market.

### The ornamental fish value chain

Ornamental (or pet fish) are produced in Jamaica for both the local and export markets (US and Canada). On the one hand, there is a handful of large producers, mostly competing in the local market, although some report also producing for the export market. On the other hand, there is a group of small and urban-dwelling fish farms scattered throughout Kingston, which are being supported by an exporting company (The Competitiveness Company). This company is responsible for the provision of materials (e.g. feed and infrastructure) and technical assistance, as well as the packaging and export of adult fish to the USA.

Further information on each of these value chains, its actors, resources and activities as well as the climate sensitivities of each value chain can be retrieved from Canevari-Luzardo (2019) and Canevari-Luzardo et al. (2019).

## Data collection

Information on actors engaged in the three value chains was first collected in consultation with three local organisations: the Caribbean Research and Development Institute (CARDI) (for the cassava industry), the Fisheries Division and the Aquaculture branch at the Ministry of Industry, Commerce Agriculture and the Fisheries (MICAF) (for information on the tilapia and ornamental fish industries), and The Competitiveness Company (for export ornamental fish). Secondary actors were identified through desk-based research, text analysis of public sources of information (and using a snowballing technique during the interviews.

A total of 136 face-to-face consultations with 121 entities were made, of which 81 correspond to interviews with primary actors (see Table 1) As part of the interviews, actors were requested to identify all their interactions within the chain (in terms of information, material and financial flows) and to discuss key factors they considered hindered or enabled their adaptive capacity. Validation workshops with the presentation and discussion of preliminary results were held for each value chain between 2016 and 2017 in Kingston, Jamaica (see Table 1).

## Value chain network mapping and analysis of quantitative and qualitative information

Relational data was extracted from the interviews into Excel and mapped with Gephi. Ego-networks were derived from the

**Table 1** Profile of primary and secondary actors interviewed under this study

| Primary actors | Cassava | Tilapia | Ornamental | Secondary actors | |
|---|---|---|---|---|---|
| Category | Number of organisations interviewed | Number of organisations interviewed | Number of organisations interviewed | Category | Number of organisations interviewed |
| Input supplier | 4 | 2 | 2 | Financial institution | 9 |
| Producer | 10 | 14 | 16 | Government | 12 |
| Producer and higgler | 3 | – | – | R&D | 4 |
| Producer and processor | 6 | 1 | – | Education institution | 4 |
| Processor | 14 | 3 | – | Business association | 2 |
| Distributor | 1 | 1 | – | Insurance | 1 |
| Exporter | 1 | – | 1 | NGO | 1 |
| Vendor/local retailer | – | 4 | 4 | Total | 32 |
| End consumer | 2 | 1 | – | | |
| Total | 41 | 26 | 23 | | |
| Field visit | 7 | 10 | 14 | | |
| Workshop participants | 31 (of which 8 were interviewed) | 14 (of which 6 were interviewed) | 16 (of which 7 were interviewed) | | |

interview data and scaled up to a spider-web. Following the terminology developed by Heath et al. (2009), a distinction was made between the 'achieved network' (i.e. interactions mapped based on elicited information), and the 'shadow network' (i.e. the relationships unmapped, but potentially present – either realised or potential). For the network analyses in Gephi, only data from actors and relationships in the 'achieved network' was used.

For each of the value chains, separate networks were produced for material, information and financial flows. Values for connectivity were derived and examined for each of these networks using network analysis functions in Gephi, with a focus on five key metrics: density, average degree, average path length, modularity, and average cluster coefficient. To explore differences in actors' centrality across the three value chains, the top 15 actors with highest out-degree centrality for each information, material and financial network were identified and the proportion of actors from different industry categories that are represented in this cohort was calculated. Actors with highest out-degree centrality across all three resource flows were also identified, to determine which actors have a key role to play in multiple resource flows. The results from the network analysis were then examined qualitatively to assess the relationship between different network structural properties and resilience principles introduced in the "Value chain resilience: definition and properties" section.

In parallel, information derived from the interviews was used to identify key factors constraining the adaptive capacity of actors across each value chain. Where constraining factors resulted from impairing network dynamics (e.g. lack of access to a particular resource), this was highlighted in the results (see Table 2). Network maps and results from the Gephi analysis were then used to identify network bottlenecks that may be influencing the rate and extent of constraining factors, as driven by relational forces. Further information on research design and stakeholder engagement is available in Annex 1 of this paper.

## Results

Interview results indicate that MSMEs across the cassava, tilapia and ornamental fish value chains are many times affected by similar adaptation constraints. Some factors relate to deeper underlying vulnerabilities within the industries (e.g. production costs), whilst others can be directly attributed to the structure of the value chain networks (see Table 2). Similar to Lowitt et al. (2015), we find that access to markets, financing and information can affect Caribbean smallholders' innovation potential. As in their study, the qualitative analysis of our interviews demonstrated that the capacity of actors to innovate and adapt is significantly enhanced when actors work collectively and collaboratively. Some of the factors constraining collaboration (such as information sharing) are strongly influenced by network, whereas others can be primarily driven by the level of embeddedness forged in business-to-business relationships, for example trust (see Table 2).

**Table 2** Challenges and adaptive capacity constraints faced by actors in the cassava, tilapia and ornamental value chains of Jamaica

| Characterisation of critical constraints | Cassava | Ornamental | Tilapia value |
|---|---|---|---|
| Production costs | X | X | X |
| Sustainable/reliable supply of raw materials and inputs | X | X | X |
| Water availability | X | | X |
| Land availability | X | | |
| Poor infrastructure | X | | |
| Access to information and training | X | X | X |
| Technical support and extension services | X | | X |
| Need for standards and regulation of markets | | X | |
| Need for coordination between producers | X | X | X |
| Lack of trust | X | X | X |
| Need for marketing strategy | X | | X |
| Regularisation and legislative framework | | | X |
| Access to finance | X | X | X |

Across all three value chains, we see primary and secondary actors represented, as well as flows of information, material and financial resources among them. The 'achieved network' illustrated in Figs. 3, 4 and 5 represents interactions forged between 75%, 86% and 60% of all actors identified for the cassava, ornamental fish and tilapia value chains, respectively.

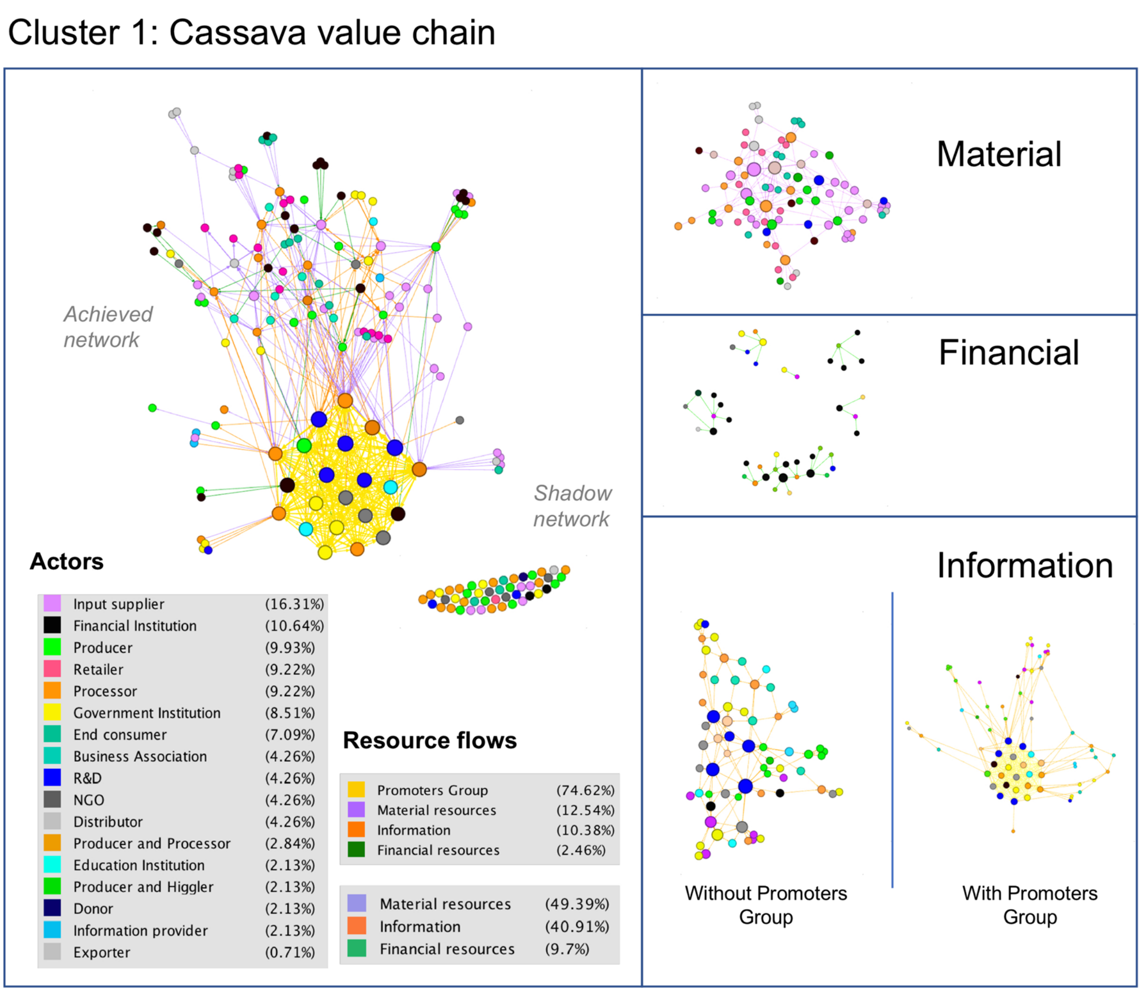


**Fig. 3** Information, material and financial network maps for the cassava value chains in Jamaica. Nodes represent primary and secondary actors and linkages represent flows of information, material and financial resources. Size of node according to out-degree value and size of edges according to weight value

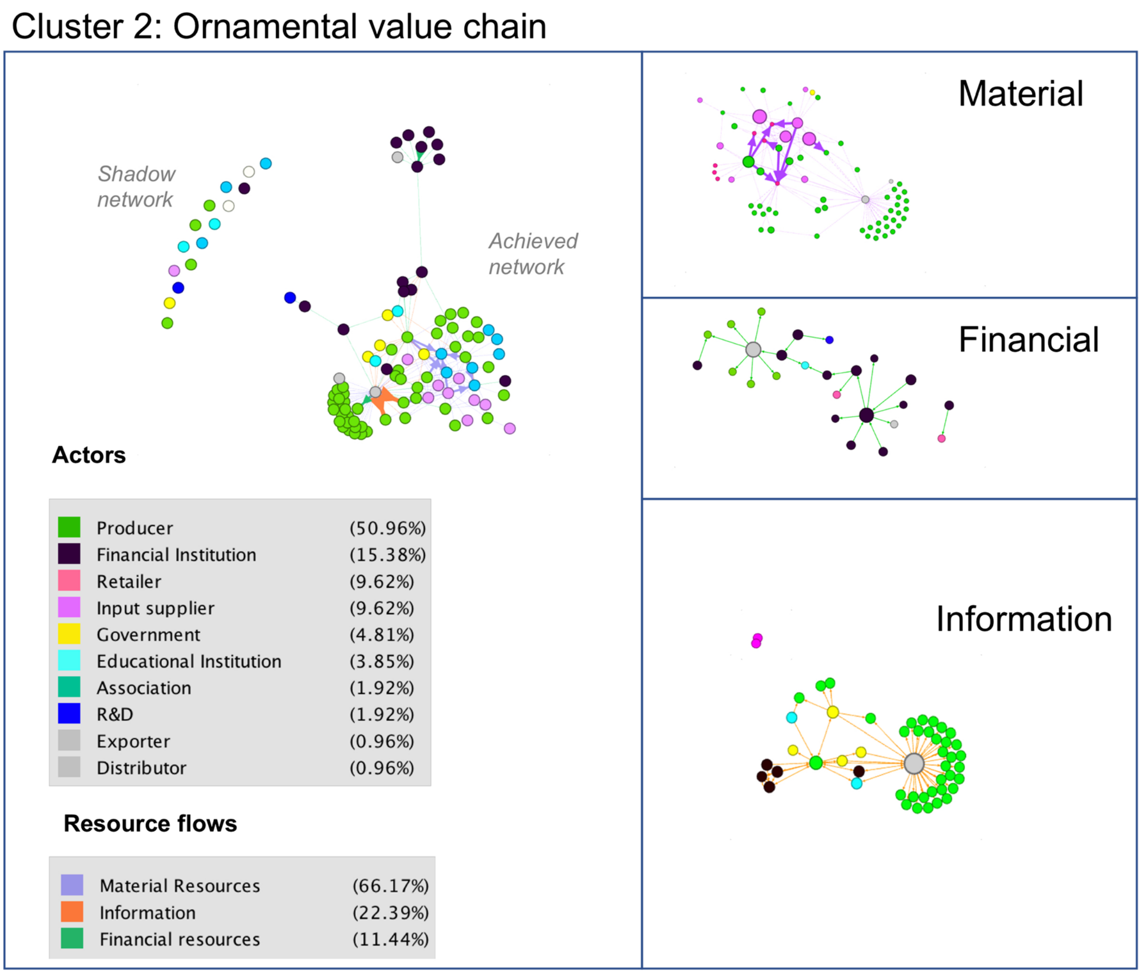


**Fig. 4** Information, material and financial network maps for the ornamental value chains in Jamaica. Nodes represent primary and secondary actors and linkages represent flows of information, material and financial resources. Size of node according to out-degree value and size of edges according to weight value

## Connectivity of information networks: the importance of business associations

Information sharing is a key attribute of resilient value chains (Kamalahmadi and Parast 2016) and was also perceived as a serious constraint to adaptation in our assessment (see Table 2). One way of testing the importance of information networks is to assess the significance of business associations.

Business associations focused on information sharing were identified in two of the sectors, cassava and tilapia:

- The Cassava Promoters Group ($N = 22$ actors): a multi-stakeholder initiative established by CARDI with the support of the European Commission and aimed at improving agricultural practices in the industry and fostering the development of cassava value-added products;
- The Hill Run Tilapia Fish Farmers association ($N = 16$ actors); and
- The Tilapia Fresh Water Fish Association (inactive for a number of years, despite expressed interest from several of their members in re-establishing its activities) ($N = 47$ actors).

Table 3 shows that information networks have higher levels of connectivity when business associations are present. This is reflected by the increased levels of density, average degree and average clustering coefficient. This means that when associations are active, the number of connection pathways, the degree of cohesion of relationships in certain parts of the network and the velocity of information sharing between actors is greater. Equally, when associations are present, the levels of modularity and average path length are lower, meaning that industry associations can reduce the number of distinct separate sub-groups within a network.

Having high levels of connectivity in information networks can help to increase resilience and adaptive capacity. As noted by (Henry and Vollan 2014), connectivity reflects the intensity of social relations and higher levels of density reflect greater opportunities for interaction as well as greater levels of social capital. However, high levels of density in information

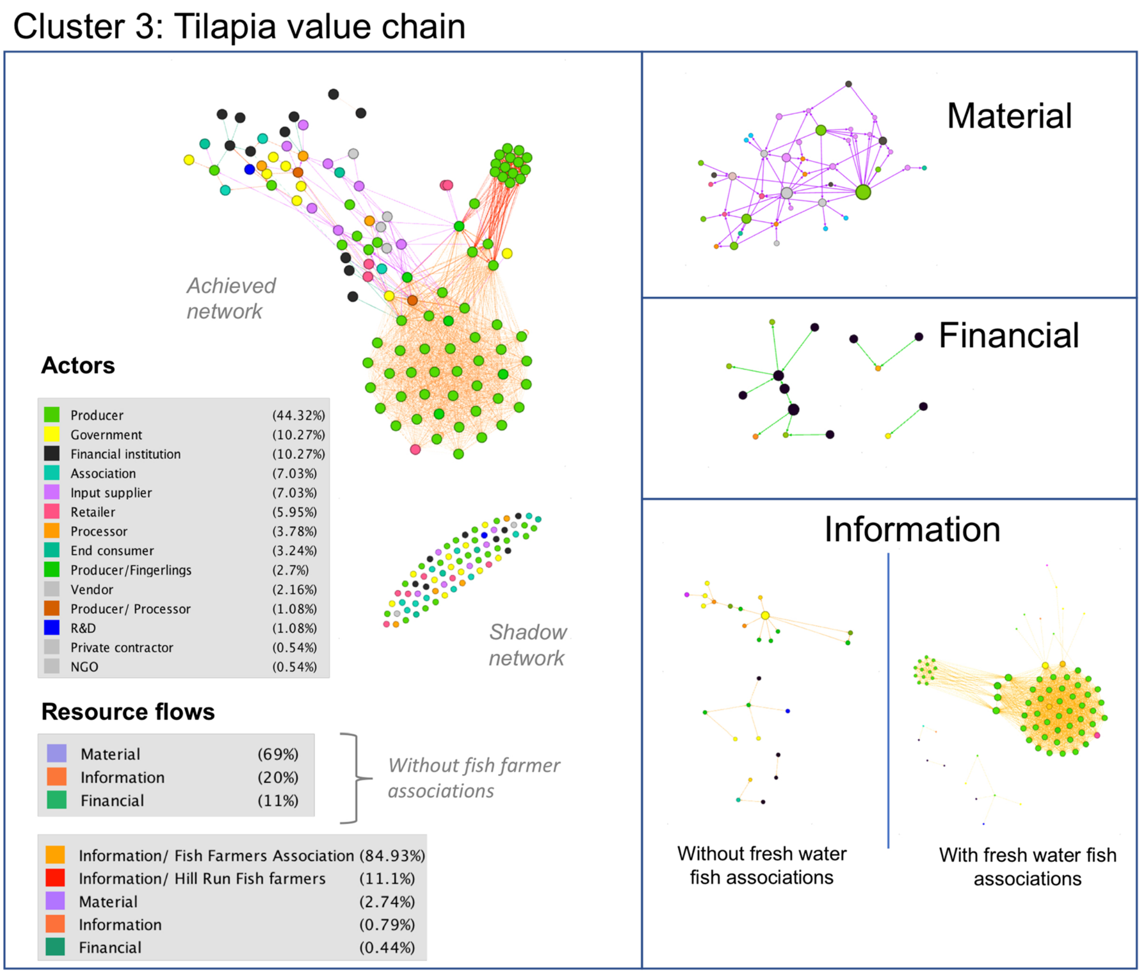


**Fig. 5** Information, material and financial network maps for the tilapia value chains in Jamaica. Nodes represent primary and secondary actors and linkages represent flows of information, material and financial resources. Size of node according to out-degree value and size of edges according to weight value

networks can be detrimental to management processes, making it difficult for decision makers to select among information sources and to build their own mental models of issues to resolve (Bodin and Norberg 2005). Concordantly, Bodin and Crona (2009)) suggest that there may be an inversed U-shape function at work, whereby increasing density can help solve information asymmetries up to a point, beyond which increased exchanges become detrimental to individual learning. It was not possible to derive the value of this potential threshold point from our results. This would possibly require

**Table 3** Comparative analysis of key connectivity network metrics for information networks in the cassava, tilapia and ornamental fish value chains

| | | No. of nodes | No. of edges | Density | Average vdegree | Average length path | Modularity | Average clustering coefficient |
|---|---|---|---|---|---|---|---|---|
| Cassava value chain | Information | 67 | 173 | 0.039 | 2.58 | 3.3584 | 0.521 | 0.04 |
| | Information (with PG) | 69 | 1098 | 0.241 | 16.118 | 2.56 | 0.139 | 0.377 |
| Ornamental value chain | Information | 49 | 72 | 0.031 | 1.469 | 2.18 | 0.428 | 0.287 |
| Tilapia value chain | Information | 26 | 25 | 0.038 | 0.962 | 1.193 | 0.661 | 0.41 |
| | Information (with Hill Runassociation) | 41 | 295 | 0.18 | 7.195 | 1.066 | 0.228 | 0.41 |
| | Information (with both associations) | 80 | 2543 | 0.42 | 31.788 | 1.4398[a] | 0.169 | 0.754 |

[a] It is possible that the increase in average path length in the tilapia value chain when a second association is included may be explained by the large number of new actors that are incorporated into the network, when the associations are active

longitudinal assessments on the evolution of a network structure, combined with further analysis on information sharing and decision-making processes.

Having some levels of modularity in a network, on the other hand, can be beneficial: It allows actors within a sub-group to develop more embedded and binding relationships. Very high levels of modularity, however, can reduce the flow of new information within a sub-group and generate detrimental dynamics of 'us vs. them' within the broader value chain network. In Fig. 6, we illustrate how modularity can be used to identify different sub-groups, in this case within the information network of the ornamental value chain.

## Role and diversity of key actors: actors' centrality

Figure 7 summarises the results from the analysis of out-degree centrality on the top 15 actors in each information, material and financial network and for each of the agricultural value chains (see Annex 2 for a detailed account on actors' centrality results with the individual names of entities included in the analysis).

We find that the cassava value chain holds greater diversity in terms of the type of key actors with high out-degree centrality for the material and financial networks, compared to the tilapia and ornamental fish value chains. Additionally, the cassava value chain holds a similar level of diversity in its information network compared to that of the ornamental fish value chain.

As one would expect, the diversity of actors is greater in information and material networks than in financial networks. We find, however, some levels of diversity in the financial network of the cassava value chain: the top 15 actors with high out-degree centrality include not only financial institutions (as expected) or government (as commonly the case in MSME-dominated value chains), but also R&D institutions, NGOs and—more interestingly—processors. This is because during the interviews it was possible to identify cases where processors provided direct financial assistance to specific producers, as a result of their long-lasting and embedded relationships.

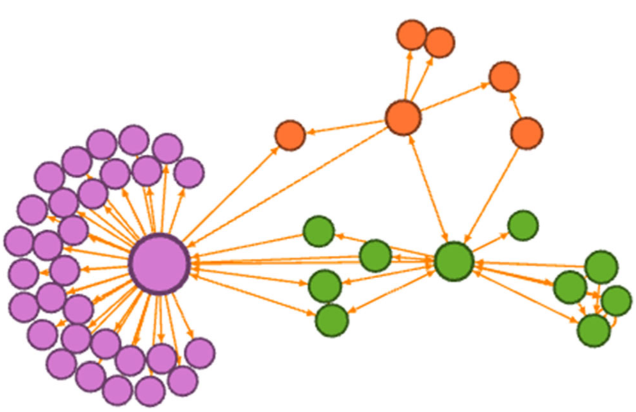

**Fig. 6** Example of network map by modularity class. In this example, we can see that the information network of the ornamental value chain is composed of three clearly distinct sub-groups

Table 4 provides a qualitative summary of the actors' out-degree centrality, presented according to each type of network flow. Overall, the results show the greater diversity of key actors engaged in the cassava value chain than in the other two value chains.

High levels of diversity among central actors can be a source of resilience in value chains. Having different types of agents carrying similar functions and operating across different networks flows can reduce the dependence on individual actors for the provision of services and resources. This, in turn, can increase the levels of network redundancy and flexibility, influencing positively on value chain resilience. It may also reduce the pressure on government agencies for the provision of critical services—such as information and financial assistance—and reduce the chances of value chain collapse if any one actor exits the network. For MSMEs, high levels of diversity can help to unlock resources that are challenging to access under normal conditions. For example, and as shown in the cassava case study, if a small-scale farmer fails at accessing a loan (potentially due to his lack of collateral), he may find an avenue to access finance through the development of strong bonding relations with a processor.

## Management implications for the development of strategies to increase climate resilience and MSMEs' adaptive capacity in the value chains selected and future areas of research

In this study, we used network analysis to understand how network properties influence value chain climate resilience, focusing on resilience attributes that help to increase MSMEs' adaptive capacity. From the qualitative analysis of interview responses, a series of structural constraints affecting MSMEs' capacity to adapt were identified; these are many times associated with broader economic and market constraints, as shown in Table 2. Successful strategies seeking to promote climate resilience across the three value chains will need to account for underlying factors constraining value chain development as well as for emerging threats generated by climate change.

But how can governments and development agencies support interventions to increase resilience in value chains and support adaptation in MSMEs? According to Borgatti and Foster (2003), network evolution primarily occurs through self-organisation. Yet, there are ways in which external interventions may help to build the resilience of value chain

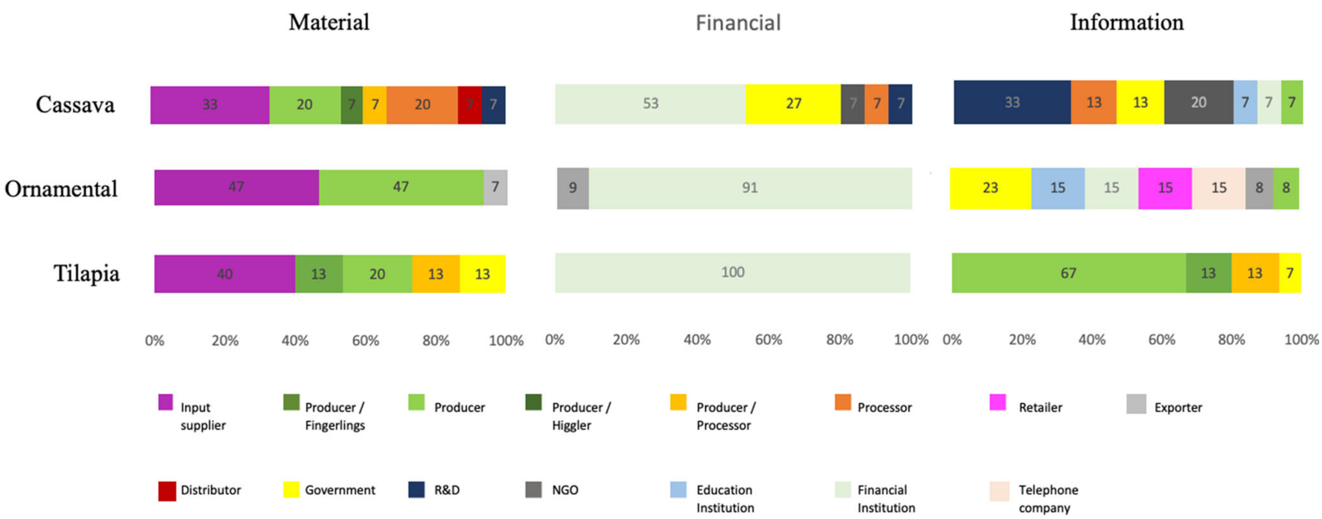


**Fig. 7** Results from out-degree centrality analyses on the top 15 actors for the material, financial and information networks of the cassava, ornamental and tilapia value chains

networks and support the adaptive capacity of MSMEs. Henry and Vollan (2014)) have argued that external network interventions can be designed to enhance sustainability outcomes through the promotion of network interactions that enhance social capital and collaboration, and interventions that help to reduce network fragmentation. We discuss three kinds of intervention that have been identified through our analysis and that could be further evaluated using the network metrics explored in this study.

## Improving information sharing with the use of network tools

Our analysis shows that the connectivity of information networks is significantly increased in the presence of business associations, providing evidence of the importance of strengthening business associations and helping to develop new interfirm relationships. Network maps can be used as a tool to evaluate where relationships should be strengthened or

**Table 4** Qualitative summary of out-degree centrality analysis on key actors operating across the different material, information and financial networks of each value chain. See Annex 3 for quantitative results

| Type of value chain | Comments |
|---|---|
| Material value chains | • In the cassava value chain R&D institutions provide access to material resources. Contrastingly, the tilapia value chain does not have R&D service providers, and has a higher reliance on input supplies provided by government than in the other two value chains. The exporter in the ornamental value chain (TCC) also provides R&D services. |
| Information value chains | • R&D agencies contribute a significant proportion of information to the cassava value chain.<br>• In the ornamental value chain, the government is the main information provider, although there is greater diversity of actors providing information due to a joint initiative between two financial institutions and two national telephone companies supporting small urban ornamental fish farmers<br>• Most information in the tilapia value chain is generated by the producers themselves, with some support from government |
| Financial value chains | • Financial institutions are the greatest providers of financial flows across all the value chains.<br>• In the cassava value chain, government agencies also provide financial support, together with R&D agencies, NGOs and processors.<br>• The tilapia value chain relies entirely on financial flows provided by financial institutions, whilst the ornamental industry also benefits from financial flows vprovided by the main exporting company (TCC). |

fostered. Defining which relationships to strengthen or develop in order to increase connectivity may be done through scenario analysis: by including or removing links between actors and reviewing the effect of such interventions on network metrics reflecting connectivity.

Alternatively, new relationships to foster can be identified qualitatively, by contrasting actor's information needs with the marginal location of actors providing these services. For example, producers in the tilapia value chain strongly agreed that they needed greater access to training on business management and best practices. However, the main organisations providing these services in Jamaica (i.e. HEART-NTA and RADA) do not currently have relationships with tilapia value chain actors (i.e. they are in the 'shadow network'). A strategy could therefore be to develop new connections between actors in the shadow network and actors in the 'achieved network', prioritising relationships with actors in the network that have greater capacity to disseminate information with others (i.e. with higher out-degree centrality).

Being able to visualise separate sub-groups through the visualisation of modularity classes can also assist targeted interventions aimed at supporting specific sub-groups, or to information is accessed by different communities. In the example provided in Fig. 6, one could assume that a minimum of three actors should be engaged (one belonging to each sub-group) in order to facilitate access to information sharing.

## Supporting and engaging key value chain actors

Out-degree analyses highlight individual organisations with the highest degrees of social influence (see Appendix 2). This information can be used when determining which actors in the value chains to engage in promoting better practices, provide key inputs to production or potentially provide financial support. Government and development agencies can provide support to actors with strong out-degree centrality, ensuring they hold the necessary resources to strengthen and expand their exchanges with others, as well as a means to increase the resilience of the value chain network. For example, when identifying key actors in the ornamental fish value chain, it was noted that a private company (The Competitiveness Company) was a key actor providing material, information and financial resources to many of the fish farmers. Strengthening the capabilities of this company to provide supporting services to fish farmers can generate benefits to the actors they engage with and ease the burden on government-based extension services. However, it is also important to analyse the power dynamics that may be influencing an actor's centrality in order to avoid enhancing power struggles and the marginalisation of vulnerable groups. Such information is reliant on qualitative analysis beyond the limits of network analysis.

The analysis of out-degree centrality also helped to identify unexpected dynamics that can inform new models of cooperation and engagement, such as the provision of financial assistance by processors to producers. Promoting the use of this model of collaboration with other processors may provide a suitable avenue for farmers seeking access to finance and equipment and reduce reliance on external financing.

## Increasing value chain climate robustness and future research

A way to examine the climate robustness and flexibility of value chain interventions would be through the use of scenario analysis. With network analysis, decision makers can generate 'What if' scenarios to determine the potential impact of a value chain disruption. This could happen, for example, by modelling the impact generated by creating or eliminating business relationships and/or business actors within a network. This can help to further our understanding on how valuable assigning resources to the development of specific relationships can be, and to better map causal chains of interactions leading to cascading impacts.

A study of the in-degree centrality of actors was outside of the scope of this analysis. This measure can however help to identify which actors are more influenced by the activities of others and can be an important network metric when examining the level of exposure of actors to cascading impacts. Future research could also further explore network analysis as a stakeholder engagement tool and the development of partial participatory approaches to network mapping, thereby examining how the provision of network visualisations and network-modelling tools can help steer stakeholders' dialogue and decisions for value chain development.

Although the study of network structural properties is primarily focused on the analysis of the effect of network properties on actors' and network behaviour (Borgatti and Foster 2003), it is also possible to develop an understanding of how external disturbances affect network evolution. As noted by Janssen et al. (2006), it is not uncommon to find inactive or 'sleeping' links to be reactivated during periods of crisis. The development of longitudinal studies to explore how network configurations change as a result of external climate disturbances, and incorporating both qualitative and quantitative data, could help us predict how networks may continue to evolve in the future. Similarly, the analysis of network evolution could be explored as a tool to monitor the impact of policies and interventions designed to increase value chain climate resilience by assessing how new interactions promoted under adaptation and resilience programs influence changes in network structures over time.

## Conclusions

This study offers the first attempt to explore the relationship between network structures, resilience attributes and the adaptive capacity of MSMEs in agricultural value chains. Introducing a conceptual framework to understand the relationship between these factors, it first examined the different elements of value chain networks, followed by an analysis of key elements that characterise value chain resilience. It then explored how elements of value chain resilience may be influenced by the network structure of the value chain, focusing on the effect of two key network structural attributes—connectivity and actors' centrality—to then infer on the effect of these relationships on MSMEs' adaptive capacity.

Using a mixed methods approach, the study applied this framework to an empirical case study, focusing on three agricultural value chains in Jamaica (namely the cassava, tilapia and ornamental fish value chains). With qualitative data derived from face-to-face interviews, we identified key adaptation constraints affecting MSMEs in each value chain. Using a series of network metrics, it then examined the connectivity and influence of key actors in the information, material and financial resource networks embedded in each of these three value chains.

In the cases explored, the study was able to assess quantitatively the importance of business associations and the role of central actors, and to link these factors to elements of resilience (redundancy, flexibility and information sharing). Through the visualisation of the networks, it was also able to identify mechanisms to target interventions aimed at increasing value chain climate resilience and MSMEs' adaptive capacity. However, the study also shows that analysing the formal structure of value chain networks is not sufficient: an understanding of the content of relational ties is also necessary, in order to understand underlying power dynamics and how the embeddedness of relationships affects network dynamics.

The operationalisation of network theory here offered, contributes to a growing field of studies applying network analysis to the study of complex natural or socio-ecological systems (Bodin et al. 2017; Dee et al. 2017; Bohan 2016). It proves that network thinking can be instrumental to understand adaptation constraints in a systematic way, and can be used to inform interventions to improve network dynamics for the benefit of MSMEs' adaptive capacity. The approach has a versatile use and can be applied at different geographical scales; in this case, it has allowed for the collection of information on nationwide interactions for value chains oriented to both domestic and regional markets.

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