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Resilience of Agricultural Value Chains in Developing Country Contexts: A Framework and Assessment Approach

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Abstract: Although agricultural value chain resilience is a crucial component to food security and sustainable food systems in developing countries, it has received little attention. This paper synthesizes knowledge from the social-ecological systems (SES), supply chain management, and value chain development literature to make three contributions to this research gap. First, we conceptualize agricultural value chain resilience and relate it to overall food system resilience. Second, we identify seven principles that are hypothesized to contribute to SES resilience, relate them to supply chain management theory, and discuss their application in agricultural value chains. A key insight is that the appropriateness of these principles are important to assess on a case-by-case basis, and depend in part on trade-offs between resilience and other dimensions of value chain performance. Third, we integrate two common tools, the Resilience Alliance's assessment framework and value chain analysis techniques, to outline an adaptable participatory approach for assessing the resilience of agricultural value chains in developing countries. The objectives of the approach are to cultivate a chain-wide awareness for past and potential disturbances that could affect food security and other essential services provided by the value chain, and to identify upgrades that can build resilience against these key disturbances.

Keywords: food systems; resilience; supply chain management; social ecological systems; value chains; sustainable development

1. Introduction

Since the 1960s, agricultural economists have been keenly interested in defining the key dimensions of food system performance that directly influence the welfare of participants and society or, more simply put, the dimensions associated with a food system doing "the things that society might reasonably expect it to do" [1,2] (p. 81). Over the years, a consensus has emerged around multiple dimensions—including product variety, price-to-cost efficiency, technological progressiveness, and equity [3]. In this article, we propose a concept originating out of the ecological sciences, resilience, as another important dimension for assessing food system performance.

Resilience is the capacity of a system to continue providing a desired set of services in the face of disturbances, including the capacity to recover from unexpected shocks and adaption to ongoing change [4]. In the last ten years, there has been a surge of interest in the topic of resilience across different academic disciplines and practice communities. Food systems is one area in which understanding resilience will be crucial, because food, nutritional outcomes, livelihoods, and many other essential life-supporting services are derived from food systems. At the same time, the rapid pace of industrialization, market segmentation, and consolidation of food systems are making them increasingly complex [5]. New challenges related to population growth, conflict, climate change, and the degradation of natural resources may be driving an increase in the incidence, magnitude, and impacts of disturbances—such as droughts, fires, price shocks, and mass population displacements—that affect the availability and distribution of food [6,7]. The nature of these shocks is often unpredictable, underlining the limitations of standard risk management paradigms that attempt to quantify the probability and outcomes of disturbances [8]. The task of understanding food system resilience is arguably most urgent for developing country contexts, where vulnerability is higher to such challenges and food and nutritional security is already tenuous [9]. Furthermore, developing countries depend the most heavily on the agrifood sector for jobs, household incomes, and economic growth [10].

Within a sustainability framing, resilience has become an important concept that allows trade-offs to be analyzed in a context of change, in order to transition a system towards more sustainable states. With respect to food systems, there is an increasing need for both design and management that improves their triple bottom line—social, environmental and economic—sustainability [11]. Building on this, the Food and Agriculture Organization (FAO) argue in their principles for sustainable food systems that "enhanced resilience of people, communities and ecosystems is key to sustainable agriculture" [12] (p. 28). This is because resilience allows decision makers to balance the functions humans desire (i.e., ecosystem services) with necessary ecosystem functions that will ensure the long-term survival of working agricultural landscapes [13].

The ability of our food systems to manage and cope with social and ecological change is critical, not just at the level of farm production but all along agricultural value chains [14]. Value chains are the set of sequenced value-creation activities that convert raw materials to final products, and the institutions that link these different production nodes. As the primary mediator between agro-ecological systems, households, and markets, value chains are an important part of the social structure of food systems [14]. Specifically, agricultural value chain resilience is essential to food system outcomes in developing countries for at least three reasons. First, stable access to markets through value chains by farms and firms is key for employment and income growth [10]. Second, value chain resilience is crucial for making diverse and nutritious foods available and accessible to consumers in the face of shocks [15]. Value chains' effect on food access is magnified for those households that also derive incomes from agricultural value chains [16]. Third, the cost-effectiveness and sustainability of development and emergency food assistance programs often depends on the ability to implement activities through existing value chains, versus through created parallel systems [16]. However, this approach requires that value chains have some capacity to continue functioning in the face of shocks, when the need for assistance is in fact most acute. Given the broad importance of agricultural value chain resilience, we believe that better understanding of this issue should be of major concern to policymakers and development agencies, as well as to the agribusinesses and farmers making up these chains.

Despite this importance, there is scant research describing the resilience of agricultural value chains in developing country contexts [16]. Three separate research streams have generated knowledge that is relevant to this issue; however, to our knowledge, no analysis has attempted to synthesize this research. The first stream is the value chain literature which, since the early 1990s, has developed an approach for analyzing commodity chains (or supply chains), by emphasizing the interconnectedness of the value-addition activities in these chains, and the corresponding issues of chain governance, coordination, and norms and standards [17,18]. While the value chain approach has been adopted to analyze social and economic equity issues, it does not provide a theory for understanding resilience [17]. However, for over three decades another literature stream that is rooted in ecology has been building a general theory of resilience for social-ecological systems (SES) [4]. While SES resilience concepts have been applied to a wide range of systems and contexts, it is a third literature stream, generated by the logistics, organizational, and supply chain management (SCM) disciplines, that has thus far contributed the most research on the resilience of supply chain systems [8,19,20]. While the SCM and value chain literature essentially examine the same unit of analysis, the latter has paid much more attention to agricultural value chains in developing country contexts. However, both have largely overlooked environmental and other sustainability issues [17].

The objective of this article is to bridge relevant knowledge from these three research streams, in order to develop a framework for understanding, assessing, and building agricultural value chain resilience, especially in developing country contexts. The three specific contributions that we make to this literature are organized as follows. First, in section two we conceptualize agricultural value chain resilience. Next, in section three we synthesize findings from the SCM and SES literatures to identify and describe principles that are hypothesized to contribute to value chain resilience. Lastly, in section four we integrate two commonly used approaches, the Resilience Alliance's assessment framework and value chain analysis techniques, to develop an approach for assessing the resilience of agricultural value chains in developing countries. To illustrate the application of the principles and the approach for a developing country context, we draw on select examples from the authors' experiences working on livestock value chains in East and West Africa. The illustrative examples are drawn specifically from dairy value chains, which are an interesting case study for resilience, given the potential contributions that dairy can make towards improving nutritional security, employment, and incomes; the important cultural role that it plays in many African societies; and the fortuitous sustainability challenges it faces [21].

2. Conceptualizing Resilience in Agricultural Value Chains

In this section, we develop a conceptualization of agricultural value chain resilience and identify factors that can enhance the resilience of these systems and their governing institutions. To do this, we synthesize insights from the SES, SCM, and value chain literatures. Our approach is to start with SES concepts, because this is the longest-running literature on resilience and because it has developed the most general and holistic theory of resilience [4,22].

2.1. Social-Ecological System Resilience and Food Systems

According to the SES framework, human activities are dependent on a multitude of social and environmental services derived from the interactions between people and nature in coupled, interacting social-ecological systems [14]. A food system is an example of a social-ecological system. Its central outcome is food security, which is commonly understood as the condition in which "all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and happy life" [23]. Other important services provided by food systems include employment, incomes, cultural benefits, and the regulation of pests and disease. The quality and quantity of SES services depend on the system's particular configuration, i.e., the specific structure and interacting dynamics of system components. Components include different value chains and, within them, farms, firms, and households that produce, consume, and supply labor to the food system [14]. These components are themselves complex systems that are coupled to their ecological and social environment, and linked to one another across space and time [4]. As we describe later, because building resilience in food systems and value chains will often imply important trade-offs, a precise understanding of the SES services that are most valued (and for which resilience is sought) is a key part of the framework.

Due to the increasing complexity of food systems and the increasing incidence and magnitude of unpredictable disturbances, there is increasing potential for food systems to cross critical thresholds, in which one of its critical components is fundamentally altered in its functions. This can lead to "large, non-linear, and potentially irreversible changes" of the system through component interactions and reverberating feedbacks throughout the system [4] (p. 7). Resilience is the capacity to influence the "fast" and "slow" variables that determine the configuration of a system and how close it is to crossing a critical threshold. For example, in a dairy value chain "fast" variables are those that are of primary concern to chain actors and are easy to measure. At the production level, fast variables might include fodder availability and prices, water availability and quality, yields, losses (due to spoilage, etc.), and the purchase price of raw milk. The dynamics of fast variables are influenced by "slow" variables such as soil organic matter, breed stocks, climate, structural changes in the dairy industry, and consumer tastes and preferences. Slow variables influence how quickly a "fast" variable may respond to external disturbances. For example, a critical threshold may be altered by crossing the genetics of a traditional dairy breed with those of foreign breeds in order to increase productivity, such that when a prolonged drought occurs the herd is not as tolerant (i.e., to reduced fodder availability) and a critical mass of the herd perishes.

The SES literature has evolved to define resilience as the capacity of a system to continue providing a desired set of services in the face of abrupt and gradual disturbances through the recovery from unexpected shocks, the avoidance of tipping points, and adaptation to ongoing change [4] (p. 7). When resilience declines, a system moves closer to its critical thresholds and, consequently, disturbances have larger effects on the system and its services [7].

A key contribution of resilience theory is the adaptive cycle, a heuristic model that outlines the four phases of cyclical change that are characteristic of SES, taking into account fast and slow dynamics [24,25]. The adaptive cycle reflects the dynamic nature of social-ecological systems, and that they are predisposed towards change rather than equilibrium. The adaptive cycle model has parallels with the industry life cycle, a well-known framework in the business literature that explains four sequential stages in industry evolution: emergence, growth, maturity, and decline [26]. However, the life cycle framework focuses on the economic forces affecting a value chain's sustainability, which is narrowly defined in terms of sales and volumes [26]. The adaptive cycle framework broadens this perspective and provides a heuristic that supports the analysis of trade-offs continuously over space and time within an SES, in order to manage for beneficial outcomes with respect to resilience and sustainability. For example, a management focus on resilience could potentially reduce economic efficiency and profitability. Many modern food systems have been managed for two economic functions—productivity and profit—with less influence by social and ecological elements [13]. This has created an increasingly rigid and less adaptive system with ever increasing control required to maintain outputs, pushing systems closer to thresholds and reducing their resilience. To increase resilience, greater diversity is required to provide back-up plans in the face of shocks, but this has trade-offs with economic functions as it requires redundancy to guarantee output over a wide range of conditions, as opposed to maximizing output over a narrow set of conditions [13].

2.2. Agricultural Value Chain Resilience

There has been recent interest in assessing and building food system resilience [27]. Three "entry points" have been identified [15]. The first is at the national or regional food system scale itself. Several authors have developed frameworks for assessing resilience, or the broader but closely-related concept of vulnerability, at this scale [7,14,15]. One advantage of adopting such a large unit of analysis is that it facilitates a holistic view of the ensemble of sub-systems and scales that together must achieve and maintain food system services, and the trade-offs within and between scales. Other papers have taken a second entry point, investigating the resilience of households, their proximate communities, or local agro-ecological systems, usually with a focus on trade-offs between farming and other livelihood activities and food security. For example, UNU-IAS et al. (2014) and Cabell and Oelofse (2012) have proposed indicators for assessing resilience at the farm or famer-community level [28,29]. The farm community is a relevant focal scale for resilience analysis because of the direct and complex social and ecological linkages that are present at this scale, and because farmers are usually seen as the population that is most vulnerable to shocks.

The third entry point is the value chain, which can also be conceptualized as a complex social-ecological system because, like food systems within which they are nested, they "incorporate multiple complex environmental, social, political, and economic determinants encompassing availability, access, and utilization" and involve varying spatial, temporal, and institutional scales with trade-offs between them [14] (p. 234). An agricultural value chain system has two layers. The first layer, which we will call value chain "components", is the stocks of resources that farms and agribusiness firms (e.g., processors, traders, and retailers) use to produce and trade. A firm's resources include its physical, financial, and human capital, as well as the capabilities to carry out complex productive and operational tasks [30]. The second layer is the institutions that govern the use and flow of resources and coordinate these activities across the value chain. This second layer includes horizontal coordination structures that govern the interaction of businesses within a given value chain segment, such as farmer organizations [31]. It also includes vertical coordination structures that govern the interactions of businesses across segments, such as bilateral contracts between businesses, and even broader structures that coordinate multiple nodes in a chain, such as value chain participant councils or commodity associations [32].

Despite its recognized importance to food system performance, agricultural value chain resilience has received very little attention in SES or value chain research (as one exception that focuses on a developing country context, see Smith et al. (2016)) [33]. In contrast, in recent years the SCM disciplines have developed a significant body of research focused on the concept of supply chain resilience. As Kamalahmadi et al. (2016) describe, this literature has emerged out of a growing consensus that supply chain risk management practices have not been sufficient to deal with many types of disturbances to which supply chains are vulnerable, namely those that are difficult to quantify ex ante [8]. While the supply chain resilience perspective has relevance for addressing predictable disturbances, its great importance lies in its potential to address disturbances that are difficult to identify in detail or for which reliable statistical information is not available. Chopra and Meindl (2016) identified two types of uncertainty that are associated with disturbances affecting supply chains. First, demand uncertainty refers to disturbances to market demand for the particular products and services that a supply chain provides to consumers [34]. Second, supply uncertainty refers to disturbances that affect the flow and value addition of products within the supply chain to their point of distribution to the consumer. These disturbances can originate from the environment outside the value chain system, as well as from within [35]. Because many supply and demand disturbances originate outside a value chain system (e.g., high frequency of drought, poor infrastructure, or unstable policy environments), a given commodity chain will likely face different levels of potential disturbances depending on its context (across time, countries, regions, etc.). As an example, Leat and Revoredo-Giha (2014) discuss in detail the different disturbances threatening a major Scottish pork value chain in the 2000s. Disturbances affecting demand included increased competition from imports and volatile exchange rate movements, while disturbances affecting supply included disease outbreaks, non-payments from processors, changing regulations on animal welfare and waste disposal [36].

Ponomarov and Holcomb (2009) provide a definition of supply chain resilience that has been identified as one of the most comprehensive, theoretically grounded, and commonly cited definitions [8,19,20,37]. According to this paper, supply chain resilience is "the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function" [37] (p. 131). Ponomarov and Holcomb (2009) also posit that supply chain resilience encompasses three phases—preparation/readiness, response, and recovery—while Hohenstein et al. (2015) and Tukamuhabwa et al. (2015) add "growth" as a fourth phase [19,20,37]. These definitions suggest that the SCM and SES resilience paradigms share similar intuition with respect to a supply chain system having both a static and dynamic aspect, the uncertain nature of disturbances, and resilience as the capacity to adapt and recover.

Further, the SCM definition of resilience usefully highlights the important role that ex ante preparation can play in preparing a value chain for uncertainties, and the immediate ex poste response to a disturbance. Although these ideas are represented in SES resilience-building principles (discussed below), they are not reflected in the SES definition of resilience provided by Biggs et al. (2015) [4]. "Growth" points to another, more meaningful objective—development—in which value chains must help to bring food security and other services to a better state" rather than merely increasing in size or continuing to provide the same set of services [38]. On the other hand, the SCM resilience paradigm tends to simplistically assume that shocks are exogenous and originate from outside the system, ignoring issues around the source and drivers of disturbances, including the supply chain's own potential influences in creating endogenous disturbances and its interactions with other systems. Examples might include conflict or natural resource degradation caused by a chain's activities. Related, the SCM conceptualization does not appear to emphasize notions of slow-moving variables, tipping points, and configurations, which are central to SES resilience thinking.

Figure 1 provides a summary of this section, and a visualization of agricultural value chain resilience. It presents a schematic of an agricultural value chain, including its system components represented by the orange boxes (e.g., the resources and capabilities used by input and service providers, or by farms) and governing institutions represented by the blue bilateral arrows (e.g., horizontal structures such as farmer organizations, vertical structures such as contracts between farmers and processors, and chain-wide structures such as value chain participation councils). It also proposes a definition of agricultural value chain resilience that is based on the SES definition, but enhanced with the ideas of preparation, response, and development, as discussed above. Specifically, agricultural value chain resilience is its capacity to continue and develop in the provision of food security and other services in the face of supply and demand disturbances, through the preparation for, response to, and recovery from unexpected shocks; the avoidance of tipping points; and adaptation to ongoing change. The value chain system is encompassed by the broader "food system," which includes other coupled systems (such as other value chains and the political system), and with which a given value chain interacts. The resilience-building principles that are outlined in green font at the bottom of Figure 1 are the subject of the next section.

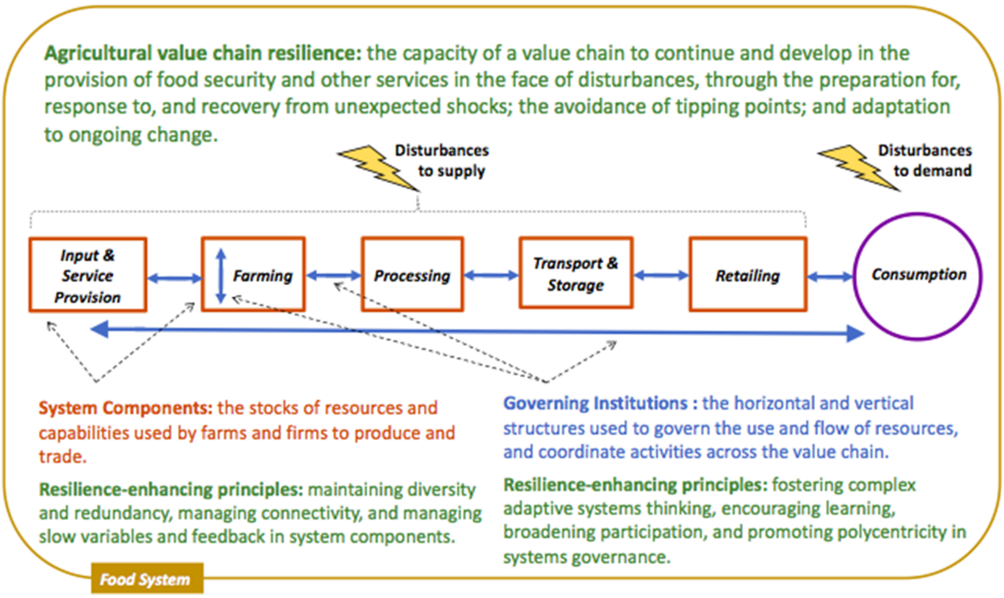

Figure 1. Agricultural Value Chain Resilience.

3. Building Resilience in Agricultural Value Chains

In their comprehensive review of over two decades of SES resilience research, Biggs et al. (2015) synthesize and assess what is currently known about factors that contribute to resilience in social-ecological systems [4]. They present seven categories of "resilience-enhancing principles" [4] (p. 18). Quinlan et al. (2016) helpfully class these principles into those that focus on building resilience in the structure and dynamics of the system components, and those focused on the structure and dynamics of the institutions governing and managing the system [27]. In the discussion below, we introduce these germane resilience-enhancing principles, reconcile them with resilience-enhancing principles that have been identified in the SCM literature, and suggest implications for agricultural value chains, using illustrative examples from African dairy value chains to demonstrate the principles (see Table 1 for further details and additional examples).

3.1. Resilience of System Components

The first three principles from the SES literature focus on the resilience-enhancing characteristics of system components [4]. First, maintaining the diversity and redundancy of system components (e.g., maintaining multiple types of milk farmers, processors, and/or distributors in a dairy value chain, and Tcommercializing multiple processed dairy product lines) provide substitutes for components that may fail in the face of a disturbance. Second, managing the connectivity between components can facilitate flows and constrain the spread of a disturbance. For example, infrastructural linkages such as roads and cell phone connectivity facilitate the flow of goods and information, while establishing traceability systems in the sourcing of raw milk can help to quickly identify and limit the spread of quality problems. The third principle is to identify and manage the key variables and feedbacks that interact to determine the configuration of a system. This builds on the first two principles, as configurations will depend on the patterns of change that system components are undergoing, for example whether milk production is increasing, decreasing, or stable, and also the linkages between components and actors, i.e., the relationship between milk productivity and investment in processing.

Two principles frequently identified in the SCM literature address the structure of value chain components. The first is maintaining the flexibility of components to take different positions and adapt operations to changing requirements with minimum time and effort [8] (p. 122) [16,19,20]. Flexibility can be linked to the diversity principle, because it is created when value chain actors depend on a diverse portfolio of human resources, products, suppliers and buyers, and income sources [19,33]. One example of flexibility through diversity is the establishment of a combination of short and long chains in a given market [33]. Diversity may contribute most to value chain resilience when businesses are heterogeneous in spatial scales, production systems, capacities and skills, and other characteristics. Thus, a processor depending on a particular agricultural input, i.e., raw milk, could build a supply base that is diverse in terms of the size and regional location of its constituent farms. Another principle from SCM, which shares the name of its corresponding principle in the SES literature, is maintaining a redundancy of value chain resources that perform the same function in the value chain [8,16,19]. Examples include maintaining safety stocks in raw milk inputs and finished processed products, cash reserves, multiple suppliers, or surplus production and transport capacity. Redundancy seems to suggest that value chains consisting of multiple competing actors at each segment are more resilient than those with high degrees of concentration, all else held constant [16].

Connectivity may be the general concept to which Smith et al. (2016) refer when they argue that small and local "scale" is an important attribute of chain resilience, since such "short chains" limit their exposure to disturbances [33]. On the other hand, the authors acknowledge that short chains are not as well connected to services as long value chains. Hauenstein (2015) explicitly refers to connectivity among value chain actors as one resilience attribute category and, with Smith et al. (2016), hypothesizes that high connectivity in the form of long and complex value chains reduce resilience, while connectivity in the form of access to services (e.g., logistics, communication) increases resilience [33,39].

Managing key variables and feedbacks appears related to the SCM principle of agility, which refers to the ability of a supply chain to rapidly respond to change through the adoption of its initial configuration [8,19]. There are two other SCM principles that are related. The first is maintaining a visibility of the structure, functioning, and surrounding environment of all chain nodes and links in real time, including early warning indicators, which can also be enhanced with information-sharing with suppliers and customers [8,19,20]. Examples include agricultural market information systems and early warning systems. The second related concept is velocity in the discovery of, response to, and adaptation to disruptions, which is especially important to minimizing losses [8,20,33]. However, managing variables and feedback requires more than just responding to prices and disasters when they occur, but will likely require the monitoring social and environmental variables not commonly captured in price and other indicators commonly disseminated by market information systems. Value chains may therefore need to set up these systems themselves, a potentially costly process that underlines the importance of carefully identifying the key variables that are most important to a chain.

3.2. Resilience of Governing Institutions

Four additional SES principles focus on the characteristics of institutions that govern and manage system resilience [4]. Of these, the first principle is to foster in institutions holistic thinking that adequately reflects the complex and adaptive nature of the systems that these institutions monitor and manage. For example, such holistic thinking in dairy value chains would consider the effects of increasing industrialization (e.g., the impacts of plastic packaging on the local environment and of livestock herds on global greenhouse emissions), as well as the vulnerabilities of dairy industry to climate change. The second principle is to encourage institutional learning that is adaptive, collaborative, and focused on multiple scales, which can aid decision-making, change perceptions and norms, and galvanize collective action. The success of dairy cooperatives in Africa has shown that such learning occurs at local scales—the challenge is extending the learning to higher scales. Third, broadening the participation of relevant stakeholders in institutions can bolster the legitimacy of systems governance, enhance information-gathering and learning about the systems, and strengthen decision-making especially in response to change. For example, in the dairy sector, bringing farmers into decision-making processes is critical to access traditional tacit knowledge alongside technology in herd management and processing. The fourth principle is to promote polycentric governance, "in which there are multiple interacting governing bodies with autonomy to make and enforce rules within a specific policy arena and geography" [4] (p. 226). For dairy, the components of polycentric governance might include farmer cooperatives that organize individual farmers at local levels; farmer unions that represent the cooperatives at regional or national levels; and different vertical value chain relationships that facilitate trade between farmer cooperatives, their input and service providers, and processors. However, one necessary condition for polycentricity to enhance resilience is that its governing bodies must be effectively coordinated in some way so that they do not work at cross-purposes, such as through dairy value chain councils (see Section 4.2 for more information and an example) and a coherent government policy framework.

A few principles from the SCM literature have some correspondence with the principles of broadening participation and promoting polycentric governance. The first principle is collaboration with other chain partners (through trade networks and appropriate and varied contractual agreements), with government agencies (through public-private partnership), and even with competitors through industry or value chain associations [16,19,20]. Better coordination with government and aid agencies before and during disturbances is an important area of coordination, as these sectors traditionally have not understood one another well [30]. Coordination activities might include linking vulnerable value chain actors to social protection (e.g., food entitlements or insurance) to maintain productivity in the chain [16]. Value chains can also advocate for their inclusion in emergency planning and programming (e.g., through local food aid procurement, or vouchers for food purchases), and develop capacities and protocols to ensure effective implementation. However, participation implies going deeper than mere collaboration, and requires more equitable participation in value chains [14]. Two other related principles from SCM are developing trust (social capital) and information-sharing (e.g., communication protocols and contingency plans) with these other actors [16,19,39].

Several other SCM principles relate to the dynamics of value chain institutions, and seem to correspond with the SES principles of fostering complex adaptive systems thinking and encouraging institutional learning. The first attribute is the creation of a "resilience culture" that develops understanding of chain structures, acknowledges uncertainties, embraces resilience-building standards and factors, and educates others [8,20]. This must originate in leadership and be operationalized in the training and education of employees (e.g., to deal with uncertainties in cross-functional teams) [8,19]. Key to a resilience culture is "innovativeness", which imbibes learning, entails participatory decision-making, and requires resource commitments [8,16,20,39].

3.3. Application of the Principles

There are three critical questions regarding the application of these resilience-building principles in an agriculture value chain. The first question is what level of resilience is appropriate for a given value chain. On one hand, building resilience in a value chain should have some positive effect on economic performance. For example, investments to improve the inflow and exchange of market information (i.e., improving connectivity) may also improve vertical economic coordination between firms in a dairy value chain. Research and development in resilient product designs—such as yoghurt, cheese, or sterilized milk—may find demand in emerging market segments. From the perspective of a value chain seeking to build competitive advantage, economic theory points to three potential pathways by which resilience could contribute to profitability [30]. First, where resilience strengthens a value chain's ability to tolerate and operate in uncertain environments, it can enable it to seize entrepreneurial opportunities by providing food products to market segments in which there is unmet demand. Second, where resilience is a unique capability that a business or value chain has developed and where it improves the marginal welfare of consumers, it can be a source of competitive advantage in a given market. Third, by enabling a value chain to prepare for uncertainty and mitigate its impacts, resilience might reduce transaction costs and the risks of opportunism within the value chain. The first two pathways suggest that resilience itself could potentially be one of the essential services provided by an agricultural value chain to its customers, and thus lead to improved economic performance through increased sales, market share, and price premiums. The third pathway would improve performance through reduced costs.

On the other hand, resilience has important trade-offs with economic dimensions of value chain performance [2]. As one consideration, the costs of building resilience (due to investments in new systems, training, maintaining reserves, etc.) could potentially reduce economic efficiency, in which case production and distribution is not performed at least-cost with respect to the market prices of inputs and existing technology [2]. Holding all else constant, under normal market conditions this translates into higher average food prices for consumers. Implementation of the diversity and redundancy principles might raise the relative costs for products that are otherwise associated with economies of scale (or scope), if it leads firms to maintain multiple heterogeneous production plants in lieu of larger facilities (or maintaining operations that are not complementary). Likewise, applying redundancy in procurement and distribution relationships may drive up the fixed costs of transacting with suppliers and buyers, and may complicate the task of managing food waste.

The concept of strategic fit can help assess the appropriate level of resilience that an agricultural value chain should have. Chopra and Meindl (2016) define strategic fit as the alignment of chain capabilities (which they summarize as "responsiveness") with the supply and demand uncertainty to which it is vulnerable [34] (pp. 27–28). Figure 2 visualizes this principle with respect to resilience. Along the x-axis is a spectrum of demand and supply uncertainty levels that can characterize a value chain and its context. Along the y-axis is a spectrum of resilience capacity that a value chain can have, which prepares it for disturbances to supply and demand. The zone of strategic fit identifies the positive relationship between uncertainty and needed resilience, all else held constant. In static situations where demand is relatively certain and there are few supply disturbances, little resilience is necessary and a value chain can focus on economic efficiency. However, as uncertainty increases, a value chain should have more resilience to address potential disturbances, all other factors held constant. Even before resilience-enhancing investments are made, a given commodity chain may already possess a notable level of resilience due to existing characteristics (e.g., a commodity's drought-resistance in production or low levels of perishability in distribution). Such a chain can operate efficiently in more uncertain environments compared to other chains that do not possess these characteristics, and that must therefore invest in additional resilience capacity. A value chain that is operating outside of the zone of strategic fit will not have optimal performance in terms of resilience. If a chain is southeast of the strategic fit zone, it has underinvested in resilience and is thus unprepared for disturbances. On the other hand, value chains that have augmented resilience to the extent that they lie to the northwest of the strategic fit zone have overinvested in resilience.

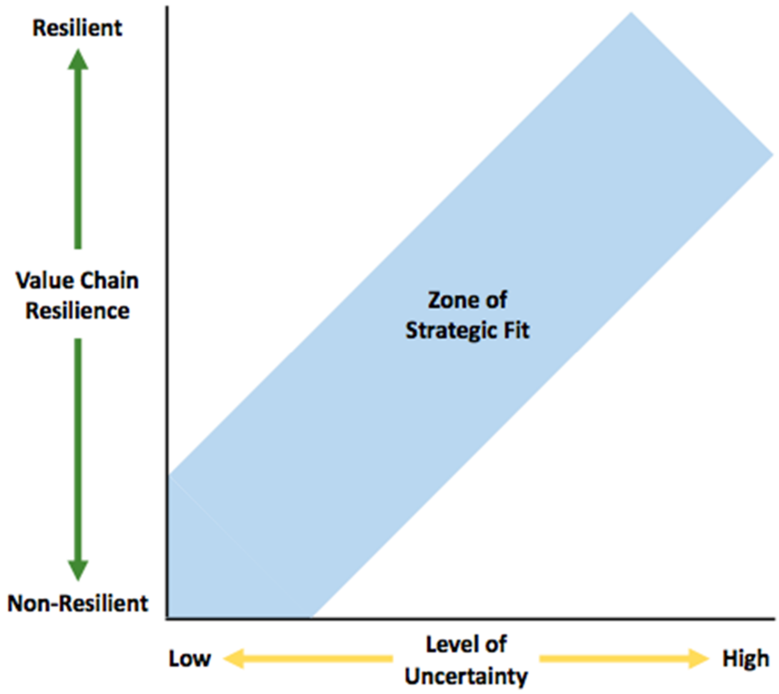

Figure 2. Strategic fit between value chain resilience and uncertainty. Adapted from Chopra and Meindl (2016, pp. 27–28) [34].

A second question that is related to how much resilience is appropriate, is which principles are most appropriate for building a given level of resilience, as resilience-building principles are highly interdependent [4]. On one hand, some principles appear to be complementary to one another, in the sense that the effectiveness of one principle might require, or is increased by, the presence of another [4]. For example, a value chain's efforts to learn and innovate effectively are likely to be facilitated by other factors, including the participation of a diverse range of businesses and actors represented within the chain, the connectivity of these actors to one another and to other actors outside the chain, and polycentric governance. On the other hand, some principles may be countervailing to one another, in the sense that one's presence reduces the effectiveness of another [4]. For example, a large degree of diversity within a value chain may actually lead to frequent conflict and reduced participation.

A third critical question is where in the value chain the principles should be applied. A value chain can oftentimes attain the desired level of resilience for the chain as a whole through different allocations of resilience to each segment of the value chain [34]. For example, investments in excess warehousing and stocking excess inventory of an agricultural commodity is a redundancy measure that may fall to a farmer organization or to its processor supplier. The optimal assignment of resilience roles and responsibilities in a value chain should be based on the comparative advantages of each segment with respect to the principle in question. For example, if farmer organizations can manage and deploy excess stock at less cost compared to its processor partner, it is the ideal segment to implement this measure. However, allocations of resilience should be made in a coordinated manner, such that its costs and benefits are equitably shared across chain partners.

The determinations of how much resilience an agricultural value chain should have, and where and how it builds this of resilience, are what Biggs et al. (2015) call "specified resilience", and critically depend on a thorough assessment of the essential services that the value chain provides as well as the potential disturbances to which it is vulnerable [4]. Making this determination is a complex task that requires careful analysis on a case-by-case basis. The aim of the next section is to outline an approach for this assessment process.

4. Assessment Approach

In this section, we operationalize the concepts and principles developed above, by developing an approach that can be used by value chain actors and their development partners to assess resilience in a given case. To do this, we adapt the assessment framework provided in the Resilience Alliance (2010) workbook, *Assessing Resilience in Social-Ecological Systems* [40]. The workbook is a thorough embodiment of the SES resilience model, and has generated the largest body of knowledge among resilience assessment methodologies [27]. However, to our knowledge it has not yet been applied to value chains. To illustrate a hypothetical application of the assessment approach, we draw on select examples from dairy value chains in East and West Africa.

4.1. Assessment Versus Measurement

Multiple tools have been developed to analyze resilience for different systems, each usually following one of two complementary approaches [27]. Measurement approaches aim to "capture and quantify resilience in a rigorous and repeatable way", which is especially useful for policymaking [27] (p. 1). Given the complex relationship between resilience and other dimensions of food system performance, the eventual development of resilience measures will be important for assessing trade-offs and judging what is good overall performance [2]. However, measurement approaches are most valid when thoroughly grounded in theory that is well-developed and tested [27]. Not only is deeper qualitative analysis of complex systems dynamics necessary to build such theory, but it is also a crucial capacity for the actors who must apply resilience thinking to make management actions [27]. Measurement-driven approaches can also tend towards an "outsider"-driven or "top-down approach", in which stakeholders might be interviewed for data but are not typically involved in the analysis process. Stakeholders may also have different, and even conflicting viewpoints compared to policymakers [39].

Therefore, following Resilience Alliance (2010), we propose a participatory approach to develop a shared understanding of system dynamics, and to collectively identify uncertainties, resilience-building opportunities, and alternative strategies [27,40]. Such an approach is consistent with participatory approaches that are often employed for value chain analyses [41], and relevant for managing "wicked problems" such as those related to sustainability [42]. In these ways, not only is the assessment approach effective for understanding the resilience of a system, but the process itself can begin to build institutional resilience through broad participation, by developing capacity for complex adaptive systems thinking and learning, and by laying a foundation for polycentric governance [27]. It is important to note that this approach does not ignore metrics, but provides the opportunity for actors to develop indicators that are contextually appropriate and for which monitoring is feasible [27,43]. Indeed, developing quantitative metrics for monitoring key variables, resilience outputs, and the effects of resilience is ultimately essential for effective management and governance.

4.2. Scope of Participation and Analysis

The appropriate scope of the assessment will depend on the case. As illustrated in section three, neither the length of the value chain (e.g., see Smith et al., 2016) nor the size of the firms within it (e.g., see Leat and Revoredo-Giha, 2014) are necessarily limiting factors. Rather, resilience is relevant to any value chain with essential services that are vulnerable to supply or demand uncertainty [33,36]. At minimum, assessment participation should encompass at least two segments of a single market channel coordinated by a lead firm or chain captain. For example, Wane et al. (2015) describes a dairy company, *la Laiterie du Berger*, which works closely with 800 farmers in northern Senegal, providing them access to animal feed, technical support, and a market outlet in return for a stable supply of high quality milk [44]. A relatively narrow scope such as these two value chain segments may be feasible and useful for individual actors seeking to improve the competitiveness of their particular channel or for addressing very local sustainability challenges.

More comprehensively, the assessment scope can encompass representatives from multiple segments and multiple market channels. For example, a more inclusive assessment of *la Laiterie du Berger*'s market channel would entail the participation not only of the company and its farmers, but also of its feed suppliers and veterinary service providers, and the key distributors of its consumer products. An even broader assessment of the Senegalese dairy value chain would consider these same segments across multiple market channels. Where possible, participation can also include policymakers, consumer groups, and development partners. This broader scope is more in line with traditional value chain analysis [39], and is a better fit for the large scale and common-pool nature of many sustainability problems [4]. However, obtaining broad support and participation for an assessment may be difficult in many contexts, and likely has the greatest success where key firms or government stakeholders are fully behind the initiative [17].

Broad assessments can be led by value chain participation councils, also known as subsector, industry, or commodity councils, or *interprofessions* [29]. In many countries, such bodies are organized to conduct joint analyses, collective problem-solving and planning, and advocacy in response to system-wide threats and opportunities that individual participants cannot address by themselves [32]. The advantages of these councils are that they can marshal information that is broadly dispersed among value chain members, and provide a structure for collaboration and consultation when interests conflict [32]. For example, Shepherd et al. (2009) describe a livestock *interprofession* in Mali (FEBEVIM) that is made up of 270 associations and companies representing farmers, traders, and processors, and which provides a number of services to its members, including organizational and production capacity building, market information, and political advocacy and negotiations. For more information on experiences and design issues related to this form of collective action, see Staatz and Ricks (2010) and Shepherd et al. (2009) [32,45].

4.3. Assessment Structure and Questions

Table 1 presents four sections of assessment questions that structure and guide the assessment. The assessment structure correlates with the major steps prescribed for a typical value chain analysis (e.g., see Trienekens, 2011), including value chain mapping and contextual analysis (parts one and three), analysis of constraints (part two), and identification of upgrading options (part four) [46]. However, as the resilience assessment approach is focused specifically on resilience as a performance dimension, it is intended to enhance rather than replace a standard value chain analysis. For example, instead of identifying the known and immediate binding constraints that challenge a value chain, part two seeks to identify past and potential disturbances that threaten the chain's sustainability. Likewise, part three seeks to describe past and potential states of the value chain, and thus takes a perspective that is more longitudinal than a typical value chain analysis. Lastly, the value chain upgrades considered in part four focus on application of the seven resilience-building principles, whereas typical analysis of value chain upgrading usually focuses on an array of options for increasing economic value and profitability. Upgrading options generally fall into several categories: improving the efficiency of operations; increasing volumes; enhancing or diversifying products, services, and markets; making functional changes within the chain; or improving chain coordination (for further discussion, see Riisgaad et al. (2010) and Trienekens (2011)) [41,46]. Applications of the seven resilience-building principles can be reclassified into these categories and can be seen as an enhancement of the value chain upgrading choice set, notwithstanding the assessment of trade-offs that must also take place.

Table 1. Resilience assessment questions and illustrative examples.

Resilience Assessment Questions	Illustrative Responses from African Dairy Value Chains
Part 1: Describe the agricultural value chain system and its essential services	
Map the value chain structure, including segments, key stocks and flows of resources, institutions, and other interacting systems.	For an example of a standard value chain analysis and mapping, applied to the Kenyan dairy value chain, see USAID, 2015 [47]. Key segments include a range of farmers, traders, processors, retailers, and consumers in rural and urban Kenya.
Identify the essential services that the value chain provides to consumers/customers, value chain actors, and their stakeholder communities.	African dairy value chains may provide a number of services, including: employment of women and youth in production and processing; remunerative incomes along the chain; food and nutritional security (protein and micronutrients) for consumers; regulation of ecosystem services; multiplier effects and improvements to national trade balance.
Identify crucial value chain components upon which the value chain directly depends, including physical, natural resources, and financial resources, and capacities.	Services may depend on natural resources (e.g., grazing lands, water, feed supplements); productive herds; traditional tacit knowledge alongside technology in herd management and processing; veterinary services; reliable market infrastructure (roads, means of transportation, electricity, cooling and refrigeration facilities); packaging to protect products and signal quality; consumers' purchasing power; liquidity; and trust among trading partners.
Describe the any key rules governing access to and use/withdrawal of crucial components, and to what extent they are effective.	Laws governing access to grazing lands, product quality standards, and competition may exist, but are often poorly enforced. Coordination structures (e.g., cooperatives and contracts) specify private rules regarding product standards and access to inputs.
Part 2: Identify disturbances that threaten the value chain system	
Reflecting on the last 10 to 50 years, identify the major disturbances that have affected crucial components of the value chain. Describe these disturbances, in terms of their probable causes, whether they were discrete "shocks" or more gradual "stressors," and their frequency of occurrence.	Past disturbances have included recurring droughts (shock), some caused by atmospheric events such as La Niña and El Niño (stressor). Since the 1990s, liberalization and privatization (stressor) have restructured market participation along the chain (e.g., privatization of services, inflow of foreign investment). Urbanization and rising incomes are driving increases in demand for dairy products and preferences for quality (stressor).
Describe the effects of each disturbance on the value chain, in terms of the different segments and functions, the provision of essential services, and the estimated time required for the value chain to recover from each disturbance.	Taking drought as one example, such a disturbance limits herd access to water and feed, and can force farming households to sell off cattle as a coping mechanism, thus negatively affecting milk supply and increasing the price of local milk. Processors and retailers could respond by substituting imported milk product for local milk. Full recovery could take several years but would depend on the type of dairy production systems in use, policy, and the intervention of safety nets, among other factors.
Identify and describe other future disturbances that could potentially affect the value chain system and its essential services.	Climate change may increase temperatures and weather volatility. Globalization may continue to shape competition, standards, demand, and preferences. Public health disasters (e.g., livestock disease outbreaks; product contamination) could tarnish value chain reputations. War or terrorism could damage infrastructure and affect services.
Part 3: Analyze system dynamics	
Assess whether the value chain is currently in a state of growth, stability, or decline, and identify the indicators that suggest this state.	Some dairy value chains may still be in an emergence stage, while others in high growth, as measured by rates of change in sales and product and market diversification.

Table 1. *Cont.*

Resilience Assessment Questions	Illustrative Responses from African Dairy Value Chains
Compare this current state to any previous ones, assessing desirable and undesirable features of each.	Value chains in high growth might be compared to nascent stages using the above metrics. Features of the early stages may include a greater level of participation in the value chain by women, better access to pasturelands, lower barriers of entry, and less uncertainty. Features of growth might include opportunities for greater productivity and higher profits, but greater import competition and restrictive market standards.
Describe the transitions between states, assessing when they took place, whether they were gradual or sudden, what caused them, and whether they are reversible.	Participants could analyze available macro data (e.g., prices, yields, supply quantities) to assess transitions and their drivers. Long-time stakeholders should be consulted regarding how and why the structure and conduct of value chains have changed over time. Structural causes might include trends related to urbanization, globalization, and technological innovation, and ecosystem changes.
Consider any other potential states that you can imagine, comparing them to current and past states and describing their probable causes.	Systems in high growth or maturity stages risk crossing irreversible thresholds into stages of rapid decline, which could be caused by any combination of the past or potential disturbances cited above. Alternatively, value chains that are in emergent or growth stages could switch to paths of slower but more sustainable growth, conditioned on regulation reforms, enhanced value chain coordination, changes in consumer preferences, etc.
Part 4: Assess the resilience of the value chain resources and governance	
Describe any actions that are currently being taken to keep the value chain from transitioning into a worse state or improving the current state, including those reflecting each of the seven resilience principles. In what segment, and against what types of disturbances, does the action build resilience? Consider any other positive effects or negative trade-offs that the action has on other actions and dimensions of value chain performance.	Participants might identify ongoing instances of diversification in terms of the types of value chain actors, production systems, dairy products and segments, and market channels; connectivity in terms of tighter market linkages and infrastructure development; market information systems and famine early warning systems that enable the monitoring of some slow and fast variables; and research, development projects, and market information systems that encourage learning.
Based on the resilience building principles, describe any other actions that could be adopted to keep the value chain from transitioning into a worse state or improving the current state, considering again where and how the action builds resilience and any other effects.	Upgrades might include better access to a diverse base of input and output markets (diversity, redundancy, and connectivity); protecting the inclusion of women and small-scale actors (participation and diversity); and integrating additional metrics (e.g., cattle breed diversity, product safety, participation rates of marginalized groups) into strategic decision-making and policymaking (complex adaptive systems thinking); and strengthening farmer cooperatives, building value chain councils, and enforcing laws that provide reasonable regulation of natural resources, product safety, and market competition (polycentricity).

Overall, the assessment structure helps participants to develop a systems-understanding in a progressive and iterative way. Each part has been designed to build on and integrate information generated from previous parts. At the end of each part, it is important for participants to summarize the information generated and to consider whether this information adds to, revises, or refines the information generated in previous parts. Also, throughout the assessment, "it is essential to confront complexity" by identifying the key variables that determine configuration of the value chain system in order to bring clarity to the assessment findings and to the actions and investments that must follow [40] (p. 9). The assessment might be implemented during the course of a one-day workshop.

To maximize this time, the workshop preparation process should include the gathering and synthesis of background information from sources such as existing value chain and sector analyses, market studies, and preliminary interviews with key informants.

The first part of the assessment focuses on understanding the value chain services for which one wants to build resilience: "resilience *of what?*" Participants define and describe the boundaries, services, and key components and institutions of the value chain system. The first step is to map out the structure of the value chain system, similarly to what is done in classic value chain analysis [36]. Essential pieces to include in the mapping are value chain segments, stocks and flows of resources (e.g., inputs, information, products, money), institutions, and important nested systems with which the value chain interacts (e.g., river systems, other competing value chains, the broader food system) (see Riisgard et al. (2010) for detailed guidance) [41]. Next, participants identify and describe the essential services generated by the value chain. This identification should include marketable products and services, especially rare attributes that meet particular customer needs and which form the basis of the value chain's comparative advantage and its economic sustainability. However, participants should also consider the broader role that the value chain plays in food security for particular groups of people, and identify other essential services (e.g., employment, multiplier effects on other value chains) provided to other stakeholders. Participants should try to prioritize the most essential of these value chain services, in order to focus the analysis in parts two and three, and to ensure that the value chain upgrades identified in part four are well-justified. Lastly, participants identify the value chain system resources that are essential to providing these services and benefits, and the rules that are in place to govern them. The resources and rules that are identified may highlight components and institutions that were previously mentioned, or introduce new ones.

The primary aim of the second and third parts is to increase understanding of the disturbances that threaten value chain services: "resilience *to what*?" They draw heavily from the SES concepts developed in section two of this paper. In the second part, participants identify and describe the major types of supply and demand disturbances that threaten the value chain system's essential services and explore their causes and effects. Participants do this by first reflecting back on actual disturbances that have occurred in the past ten to fifty years, then by imagining other disturbances that could likely occur in the future. The third part applies the adaptive cycle model to the value chain to assess system dynamics. As in the second part, participants first consider past configurations in which the value chain has been, then imagine better or worse. For each, participants analyze the variables and thresholds that drive transitions between configurations states (see Chapter 2 of Resilience Alliance (2010) for more details) [40].

The fourth part focuses on *how to build* resilience of value chain services to the major disturbances that threaten it. First, participants identify and describe the resilience-enhancing principles that are already being employed to address disturbances, and analyze their effects on resilience and other dimensions of value chain performance. Secondly, participants consider other resilience-enhancing upgrades that could be implemented. For each upgrading option, participants should thoroughly assess the effects on other dimensions of value chain performance, the potential synergies and counter-vailing relationships between the upgrading options, which value chain stakeholders are best positioned to implement these upgrades, and how the costs and benefits will be shared in an equitable manner.

As discussed, building an appropriate level of resilience will sometimes require the value chain to make significant capital investments or operational changes that increase the per unit cost of its marketable goods and services. Value chain stakeholders should rigorously assess customers' willingness to pay for the increased resilience value. In cases where the market is not ready to compensate for these added costs, the value chain can consider developing communication and marketing strategies aimed at influencing preferences towards more sustainable consumption. Where resilience generates positive externalities outside the chain, the value chain actors should also consider developing partnerships with other industries, government, or other food system stakeholders, to help share the costs. To these ends, the information and findings emanating from the assessment can be used as an input for business strategies, or leveraged to design future research, organize additional stakeholder meetings, conduct advocacy, or petition for project funds. Depending on the objective, Rissgard et al. (2010) (pp. 212–213) recommend selecting "action points" through which desired change can be stimulated [41]. Assessments are time-sensitive, and should be regularly revisited, e.g., every strategic cycle or as key contextual factors change.

5. Conclusions

This paper has introduced a concept originating out of the ecological sciences, social-ecological system resilience, as an important dimension of food system performance. Specifically, we have conceptualized agricultural value chain resilience as the capacity of a value chain to continue and to develop in its provision of food security and other services in the face of disturbances, through the preparation for, response to, and recovery from unexpected shocks; the avoidance of tipping points; and adaptation to ongoing change.

Drawing from over three decades of social-ecological system research, we have discussed the application of seven resilience-enhancing principles to the resources, capacities, and institutions of an agricultural value chain, while drawing attention to their interactions with one another and the potential synergies and trade-offs that these principles might have on other performance dimensions, including profitability and food prices. The operationalization of each principle, its effectiveness in building resilience, and its broader impacts will depend highly on the commodity, context, and the disturbances that are of concern. Investigating these questions is a crucial area for future research. As part of this, additional theoretical work should be done to develop precise measures for agricultural value chain resilience, in order to further clarify the resilience concept, compare and aggregate resilience across observations, and to analyze tradeoffs with other performance dimensions.

These research gaps, however, do not preclude individual value chain actors from working through these questions and assessing resilience for their particular case. For this task, we outline an agricultural value chain resilience assessment approach from a well-cited framework. The objectives are to cultivate a chain-wide awareness for the disturbances that have affected (and could affect) the essential services provided by the value chain, and identify upgrades that can build resilience against key disturbances. The approach can be adapted for use by particular value chain actors or more broadly by value chain councils. We anticipate that the concepts and methods should also be of interest to government and development partners wishing to incorporate resilience into agricultural policy and development programs.

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