Operationalizing food system resilience: An indicator-based assessment in agroindustrial, smallholder farming, and agroecological contexts in Bolivia and Kenya

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1 Introduction

Food systems illustratively link society and nature (Blesh and Wittman, 2015): They are social-ecological systems (Berkes and Folke, 1998; Ericksen, 2008a; Ostrom, 2009) comprising actors – their needs, interests, knowledge, and institutions – determining how to produce, distribute, and consume food, correspondingly giving rise to different impacts on ecosystems. While agricultural yields have increased when measured globally, poor distribution and poor food quality have meant rising numbers of both hungry people and obese people (FAO, 2017), pointing to serious flaws in our food systems inherited from the last century (De Schutter, 2014). Other signs of food system weakness include the erosion of local and national food security in various areas due to the problematic convergence of import/export dependencies, dietary reliance on a narrow range of crops, and climate change impacts, especially in the global South (Bren d'Amour et al., 2016).

Properly addressing the manifold trade-offs between global food production/consumption and environmental, social/cultural, and economic dimensions requires going beyond the common focus on maximizing yields, and instead focusing on optimizing the complex interactions of food production, environmental impacts, and social justice outcomes (Godfray et al., 2010). It is necessary to better understand – and eventually act upon – the dynamic interplay of different food systems and their social, economic, political, and ecological effects, thereby situating food security within the wider concept of *food sustainability* (Lang and Barling, 2012).

Rist et al. (2016) developed an operational concept of food sustainability. It classifies food systems as sustainable if they are able to strike a positive balance between five fundamental aspects: (1) the capacity to ensure food security; (2) to fulfil people's right to food; (3) to reduce poverty and inequality; (4) to exhibit a high environmental performance; and (5) to exhibit high levels of social-ecological resilience. From this concept of food sustainability, we thus derive the need for improving food systems' resilience and, by extension, their sustainability so as to ensure human well-being and ecological functioning. Resilience refers not only to the capacity to absorb stress and shocks as a system, but also to the capacity for self-organization and learning among

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system actors. In this way, resilience is a dynamic concept (Ericksen et al., 2010), accounting for fast and slow changes that must be addressed at multiple interaction scales (Anderies et al., 2006). Overall, resilience may be considered a system property that plays a critical role in the sustainability of food systems.

Resilience is not intrinsically positive, however, and must therefore be embedded in a broader normative framework (see Hodbod and Eakin, 2015). For example, a food system that produces negative environmental or health impacts may be resilient in the short term, but not sustainable or desirable. To identify steps towards increasing long-term food system resilience, the actors involved must co-develop a vision and related values regarding the desired direction of development. Further, Toth et al. (2015) make an important distinction between the concepts of food security and food resilience: While *food security* is an *outcome* of food systems – in terms of the availability, accessibility, and utilization of food (Ericksen, 2008b) – *resilience* corresponds to the ability of food systems to withstand shocks as well as to learn and adapt to changes in external and internal conditions. In this way, resilience represents a broader concept than mitigation of vulnerability. Resilience refers more expansively to the ability of a food system to produce and distribute food under changing conditions, and, if linked to a normative framework such as the concept of food sustainability, to do so in a way that is equitable and sustainable in both the short term and the long term (see Toth et al., 2015). Additionally, Smit and Wandel (2006) state that vulnerability reduction appears most effective when undertaken in combination with strategies and plans at various levels, pointing to an added value compared to regarding resilience simply as the opposite of vulnerability. While vulnerability describes a set of conditions that prevent people from overcoming adverse events, resilience comprises a set of responses where one response may address various vulnerability factors (FSIN, 2010)**.** Sage (2014:255) conceptualizes resilience as a "*desired state to which communities aspire, representing the capacity to absorb disturbance while undergoing changes to retain essentially the same functionality, structure, and identity*", and links the concept to food system transformation. Jones and Tanner (2016) have sought to shift the theory of resilience away from conceptualizing the return of a given system to its "original" state and towards conceptualizing the root causes of vulnerability and loss of resilience. Together with other previous work – e.g., that of Ericksen et al. (2010) who state that resilient food systems should have the potential to create opportunities for innovation and development – the relevance of the concept of resilience to transformation becomes evident.

To date, few research studies have applied resilience thinking to sustainability assessments of food systems. Food-related resilience studies have analysed specific components of food systems (Tendall et al., 2015), including: the resilience of agroecosystems and pastoral systems to climate change (Choptiany et al., 2017; Molina-Murillo, 2017; Heckelman et al., 2018); the role of different forms of knowledge (Anderson 2015); functional and response diversity (Hodbod and Eakin, 2015); as well as global comparisons of national income levels, yield gaps, and food calories produced (Seekell et al., 2016). Ifejika Speranza et al. (2014) applied resilience thinking to livelihoods, conceptualizing resilience as a system property and component of sustainability corresponding to the ability to adapt to or handle social-ecological change, thereby providing an example of operationalization. Our research builds on the theories of Tendall et al. (2015) and on the conceptual-empirical work of Ifejika Speranza (2013; 2014), applying a resilience assessment to food systems as part of their sustainability performance. The present study was part of a larger research project on food system sustainability in South America and

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Africa (Rist et al., 2016). The project study areas were in Kenya and in Bolivia, with each study area featuring different types of food systems and figuring prominently in the respective national food supply. Both Bolivia and Kenya have the human right to food enshrined in their constitution (Kenya in 2010; Bolivia in 2009) and may be considered innovative in this respect. With the aim of contributing to the operationalization of resilience thinking in research on food systems, we conducted a parallel assessment in Kenya and Bolivia based on the following research questions:

(1) What is the state of social-ecological resilience in different, coexisting food systems in Kenya and Bolivia?
(2) What are the key differences or similarities that reduce resilience in the selected food systems?
(3) What are the main identifiable leverage points or potentials for increasing resilience in the different food systems?

2 Materials and Methods

2.1. Operationalizing resilience in three dimensions

To apply the concept of resilience to food systems, we used the three core dimensions of resilience proposed by Carpenter et al. (2001). Application of these three resilience dimensions – i.e. buffer capacity, self-organization, and the capacity for learning and adaptation – makes it possible to join biophysical and social aspects of “resistance”, and include the dynamic component of organization and adaptation. In this way, the rather abstract overarching concept of “resilience” may be made operational and indicators can be identified. Further, we primarily used Cabell and Oelofse’s (2012) indicator framework for agroecosystem resilience to assess these three core dimensions, adapting the framework to food systems by drawing on additional literature as outlined below.

(1) *Buffer capacity*: referring to the capacity of a system and its properties to cushion against stresses and shocks. The state of and access to livelihood assets – i.e., natural, human, financial, social, and physical capital (DFID, 1999) – indicate the resilience of the actors in a food system (Alinovi et al., 2010; Ifejika Speranza et al., 2014; Lisa et al., 2015). We considered whether food system activities generate a livable wage/income when assessing financial capital (Cabell and Oelofse, 2012), and considered people’s autonomy in decision-making when assessing social capital (Rotz and Fraser, 2015). Further, the diversity of system components is key to resilience (ibid.). To assess this indicator, we considered the diversity of crops and breeds (variety level) on farms. Many connections among a diversity of system components ensure a wide range of possible responses to external or internal challenges and enable redundancy (Altieri, 2013), permitting the food system to adjust to losses and to buffer against shocks.

(2) *Self-organization*: referring to the degree to which actors in a food system are capable of controlling system processes as well as to self-regulation, or the extent to which food system processes interact to keep the system functioning. Following Anderson (2015) and Carpenter et al. (2001), resilience is related to the degree of decentralization of system functions, for example, whether or not and to what extent there are proximate or direct trade relations, or many middlemen in a value chain. A related indicator is the level of reliance on local vs. external resources in food system processes. Examples of assets that enhance regeneration are seed banks, landscape elements that provide habitat for biodiversity, as well as interest groups and solidarity networks (Evans, 2011; Altieri, 2013). Finally, Rotz and Fraser (2015) recommend

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analysis of connectivity, in which we included the factors of trust and competition/cooperation among food system actors (Anderson, 2015).

(3) *Capacity for learning and adaptation*: adaptive capacity helps to increase a system's buffer capacity and refers to "a component of resilience that reflects the learning aspect of system behavior in response to disturbance" (Carpenter, 2001:766), which adds a dynamic long-term component to resilience thinking (Smit and Wandel, 2006). Adaptive capacity is largely locally determined (ibid.), e.g., based on a legacy of local-traditional knowledge regarding natural resource use, and a shared vision of the food system. Simply put: "Resilience is maintained when buffer capacity exists and is not declining, self-organization exists and is promoted, and learning occurs" (Ifejika Speranza et al., 2014:112).

2.2 Indicators for food system resilience

Indicator frameworks for assessing resilience have become increasingly important (Carpenter et al., 2001; Walker et al., 2002; Cabell and Oelofse, 2012; Ifejika Speranza et al., 2014; Lisa et al., 2015; Blesh and Wittman, 2015; Choptiany et al., 2017; Heckelman et al., 2018). Hodbod and Eakin (2015) note that food system resilience needs a normative component that asks "Resilience for what?" In the present study, we view the purpose of resilience as that of learning from the past and building capacity to withstand current and future stresses and shocks, thus contributing to food system sustainability. This approach implies using a set of indicators that reflects such a normative component. The indicators of food system resilience used in our analysis are based on resilience literature, and on our previous work on livelihoods and agroecosystem resilience (Ifejika Speranza, 2013; Jacobi et al., 2013). We revised the indicators together with our regional research partners to ensure local relevance (namely, researchers from the University of San Simón, Cochabamba, and the NGO Probioma in Bolivia; researchers from the University of Nairobi, and the research and training centre CETRAD in Kenya). Our collaborative work gave rise to the (non-exhaustive) set of indicators presented in Tables 1a, 1b, and 1c. Then, we established criteria for rating of the indicators on an ordinal scale, which allowed us to aggregate ratings for both qualitative and quantitative information (see 2.4, and Tables 1a, 1b, and 1c) – again according to local relevance and collaborative assessment. We collected information from key actors in different food system stages (production to consumption), focusing on those actors whose livelihoods were directly linked to the respective food system. We also considered information on the roles of politics, information and services, and natural resources, based on secondary data from official statistics, municipal development plans, non-governmental organizations (NGOs), and scientific literature.

Table 1a

Indicators and rating criteria for the resilience dimension of buffer capacity.

Indicators	**Description**	**Rating criteria used in this study**
Diversity of crops and breeds	The diversity of crops and breeds on farms, and/or in markets, and/or consumed related to the respective food system as a proxy for the diversity of system components (Ifejika Speranza, 2013; Rotz and Fraser, 2015). Diversity of system components including seeds creates redundancy (Altieri, 2013; Bahadur et al., 2013; Candy et al., 2015) and	Average crop and breed species richness as a percentage of the maximum in the sample, transferred to a five-point Likert scale. 0=monocrop/breed, 4=highest diversity found in the sample.

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	response diversity (Biggs et al., 2012; Kahiluoto et al., 2014).	
Natural capital[a]	Land ownership; soil fertility; access to drinking water; access to irrigation water.	Average rating from: access to land; soil fertility; access to drinking water; access to water for irrigation. 0=inexistent, 1=low, 2=significant, 3=high, 4=desirable/ideal.
Human capital[a]	Family involvement/work in the respective food system activities; years of experience in the food system activity; education: years of schooling; skills and capabilities regarding the food system activity; state of health in the family and access to healthcare (see DFID, 1999; Ifejika Speranza, 2013).	Average rating from: the existence of family involvement/work in the respective food system activity; experience in the food system activity; years of schooling; health in the family; and access to healthcare 0=inexistent, 1=low, 2=significant, 3=high, 4=desirable/ideal.
Financial capital[a]	Income sources related to the food system; whether or not monthly per capita wage levels or incomes from food system activities at any food system stage are above minimum wage (see Cabell and Oelofse, 2012).; food expenditures; other expenditures; savings; debts; loans; state support; other support (DFID, 1999; Toth et al., 2015).	Average rating from: the existence of income sources of different food system actors related to the food system; levels of wages/incomes; food expenditures; other expenditures; savings; debts; loans; state support; other support. 0=inexistent, 1=low, 2=significant, 3=high, 4=desirable/ideal.
Social capital[a]	Membership or participation in social networks (Ifejika Speranza, 2013); community/reciprocity mechanisms; decision-making autonomy and related bargaining power (DFID, 1999; Altieri, 2013; Sage, 2014; Candy et al., 2015).	Average rating from: the existence of and participation in social networks; use of group tools, equipment, or infrastructure, participation in decision-making. 0= inexistent, 1=low level of participation in networks and decision-making 2=significant, 3=high, 4=desirable/ideal, food system actors feature similar bargaining power.
Physical capital[a]	Housing and other installations; access to inputs, machinery and tools necessary for the system to function; access to transport, storage facilities, sanitary services; water, electricity, gas, waste management (see DFID, 1999). Number of livestock in tropical livestock units (DFID, 1999; Ifejika Speranza, 2013)	Average rating from: the existence of housing and other installations; sanitary services; other services (water, electricity, gas, waste management; access to inputs, machinery and tools; access to transport) 0=inexistent, 1=low, 2=significant, 3=high, 4=desirable/ideal.

[a]Indicators aggregated from other studies in the overall research project (Catacora Vargas, 2017; Mutea, unpublished)

Table 1b

Indicators and rating criteria for the resilience dimension of self-organization.

Indicators	**Description/factors**	**Rating criteria used in this study**
Decentralization and independence	The indicator "Globally autonomous, locally interdependent" (Cabell and Oelofse, 2012) may refer to reliance on local resources (Ifejika Speranza et al., 2014); direct trade relations (as opposed to many middlemen); diversified/local vs. external input sources; local economy cycles; and less dependency on input and commodity markets (Cabell and Oelofse, 2012).	0=All inputs (main materials and knowledge) are external; markets are mainly dependent on external actors; no local markets. 1= Most inputs and knowledge are external; markets are external; however, some local cycles such as reproduction of seeds can be identified. 2= Knowledge, inputs, and markets are partly external and partly local; 3= Only parts of the inputs (e.g. some seeds or some specialized knowledge) comes from non-local sources, markets are mainly local. 4= No external inputs, only local markets.

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Local consumption of production	The proportion of food that is produced and consumed locally or on-farm. This indicator is a proxy for the relevance of a food system for local food security, identity, knowledge, agrobiodiversity, and the possibility of relying on local production in case of disturbances (Altieri, 2013).	Percentage of production that is consumed on-farm or locally, i.e., by the producers' households, or sold in local markets. 0=Nothing; 1= Up to 25%; 2= 25–50%; 3= 50–75%; 4=75–100% of the food produced is consumed locally.
Interest groups	Organization of food system actors in interest groups within and across food system levels, for example in cooperatives, chamber of commerce etc. Relevant factors include: the number of interest groups connected to the food system; whether or not they link different food system stages; and whether or not they cover different scales, i.e. local-national-regional-global (see Cabell and Oelofse, 2012; Altieri, 2013).	0=No interest group identified in any of the food system stages or at any scale, local to global; or very few interest groups, only in one or two food system stages, and restricted to the local level. 2=More than one interest group at more than two food system stages, not restricted to the local level or at only one scale. 3=Various interest groups covering more than two food system stages from the local to the international scale. 4=Various interest groups in all food system stages covering all scales from local to global.
Ecologically self-regulated	Provision of habitats for biodiversity through landscape diversity, and ecosystem services (Cabell and Oelofse, 2012). Examples include: protected areas; buffer zones or green corridors; agroecological soil management; incorporation of perennial plants; recycling of residues; mixed cropping; crop rotation; agroforestry; reforestation with native species; animal refuges; water harvesting and drainage (Altieri, 2013). Average number of different land cover classes per farm area as a percentage of the maximum in the sample.	0=No positive contribution to landscape diversity, implying the number of different land cover classes; degradation of soils and ecosystem services. 1=Minimal detectable contributions to increasing biodiversity such as protected areas or green corridors; agroecological soil management; recycling of residues; or diversity of production and consumption. 2=Medium contribution via more than one of these or other measures that provide habitat for biodiversity in at least two food system stages. 3=High contribution via at least two such measures in at least two food system stages. 4=Different measures contributing to the provision of habitat for biodiversity at all food system stages.
Appropriately connected	Connectivity of food systems refers to the quantity and quality of connections within food systems, and whether there is competition or cooperation (Biggs et al., 2012; Rotz and Fraser, 2015). Connectivity can create both resilience and vulnerability (Biggs et al., 2012). Thus, we added solidarity networks (Altieri, 2013) and trust relationships (Ifejika Speranza et al., 2014; Anderson, 2015). Measurable factors are: (1) connections between a) food systems and b) food system stages; (2) cooperation including solidarity networks among a) food systems and b) food system stages; and (3) whether or not different food system actors trust each other.	0=No indication of cooperation, trust relationships, or solidarity networks. 1=Some indication of connection, cooperation, trust, or solidarity networks across a few food system stages or food systems. 2=Connection and cooperation, trust and solidarity networks between some, but not all food system stages and/or food systems. 3=All food system stages and/or food systems are connected, but not all cooperate with each other, and not all have a high degree of trust or solidarity networks. 4=All food system stages and/or food systems are connected, feature trust relationships, and solidarity networks.

Table 1c

Indicators and rating criteria for the resilience dimension of capacity for learning and adaptation.

Indicators	**Description/factors**	**Rating criteria used in this study**
Knowledge of	Ability to work with uncertainty and change (Bahadur et al., 2013): actors' awareness and ability	0=No actor at any stage is aware of risks or opportunities. 1=Actors are aware of risks or

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threats and opportunities	to assess, monitor, and cope with threats facing food systems; and actors' awareness of opportunities (Ifejika Speranza et al., 2014). Examples include disturbances to that the system has been exposed to, perceptions of them, and about how people react to them (Altieri, 2013).	opportunities at one stage at least. 2=Actors from most stages are aware of risks, but not opportunities. 3=Actors from all stages are aware of risks and opportunities, but cannot always make use of opportunities. 4=Actors from all stages are aware of risks, and make use of opportunities.
Reflective and shared learning	Access to and quality of learning activities; Food system actors proactively create desirable futures based on experience rather than simply react to present conditions (Cabell and Oelofse, 2012). Components include: availability of and participation in courses such as farmer field schools; participation in community development activities (e.g., school meal organization, environmental activities such as planting and taking care of trees, seed banking, haymaking, etc.).; and commitment to learning (Ifejika Speranza et al., 2014).	0=No activities, commitment, or indication of creation of a desirable future at any stage and by any actors groups. 1= Activities, commitment to learning, and/or indication (one or more) at one stage or in one group of actors. 2=Activities, commitment to learning, and/or indication of one or more of these at one or more stages of the food system in one or more actor groups. 3=Some activities, commitment, and indication of creating desirable futures (one or more) at all stages of the food system/among all key groups of actors. 4=Activities, commitment, and indications for the design of desirable futures according to the food system logic at the principal food system stages among all groups of related actors.
Functioning feedback mechanisms	Information sources; new ideas and practices learned; and support mechanisms (see Ifejika Speranza et al., 2014). Factors that can be taken into account: (1) mention of information sources; (2) new ideas and practices learned and applied, e.g., implementation of agroecological management principles; (3) support mechanisms, e.g., social security, food relief, yield insurance, and subsidies.	0=No indication of information sources, new ideas and practices, or support mechanisms at any food system stage among any group of actors. 1=Indication of information sources, new ideas and practices, or support mechanisms at one stage or among one group of actors. 2=Indication of information sources, new ideas and practices, or support mechanisms at one or more stages among more than one group of actors. 3=Indication of information sources, new ideas and practices, or support mechanisms at one or more stages or among all groups of important actors. 4=A variety of information sources, new ideas and practices used and support mechanisms at all food system stages and among all groups of actors.
Existence and use of local-traditional knowledge	Biological and cultural memory, identity and knowledge embodied in a system and its components (Cabell and Oelofse, 2012). An important factor used here as a proxy is: (1) existence and (2) use of local-traditional knowledge. Factors we took into account were the maintenance of heirloom seeds and recipes; combining traditional forms of cultivation; processing, distribution, and consumption of new knowledge; and the knowledge, consultation and involvement of elders (Bahadur et al., 2013).	0=No indication of use of local-traditional knowledge in the food system. 1=Existence of local-traditional knowledge (but seldom or very rarely implemented) at one stage, at least, or among one group of actors. 2= Existence and use of local-traditional knowledge at one food system stage or among one important group of actors. 3=Existence and use of local-traditional knowledge at more than one stage and/or among more than one group of actors. 4=Existence and use of local-traditional knowledge at all stages and among all important groups of actors in the food system.
Shared vision	A shared vision among the different actors of a food system that points to a normative dimension by asking "resilience for what?" (Hodbod and Eakin, 2015). Values and attitudes of different stakeholders (Eakin, 2010; Altieri, 2013; Bahadur et al., 2013) about the kind of food system they want to create and represent. In this study, we focused on the existence of a shared vision among the different groups of actors in the food system, referring both to statements and actions taken.	0=No indication of a shared vision about the food system. 1=Shared vision regarding one aspect of the food system among one group of actors at one stage. 2=Shared vision among two or more food system stages or among two or more groups of actors regarding one or more aspects of the food system. 3=Shared vision among most actors of the food system regarding several food system aspects. 4=Shared vision among all important groups of actors in the food system regarding several food system aspects.

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2.3 Study areas

Field studies were conducted in Kenya's northwestern Mt. Kenya region, and in Bolivia's Santa Cruz Department. Both study areas include a strongly export-oriented agri-food sector. Both areas are key to their respective local and national food supplies, while undergoing rapid agrarian and livelihood change linked to different food system activities (Rist et al., 2016). The settings feature diverse modes of food production, distribution, and consumption regarding economic, ecological, and socio-cultural implications (Table 2). In Bolivia, we selected the municipalities of San Pedro and Samaipata as case study sites. In these municipalities, different types of food production, distribution, and consumption may be observed. In the monoculture-dominated landscape around the city of Santa Cruz, indigenous and smallholder food systems are increasingly shifting to agroindustrial food systems characterized by soybean (and some food grain and sugarcane) production, processing, and commercialization. Soybean cultivation is rapidly expanding into the semi-arid Chaco region, where indigenous Guaraní communities partly maintain traditional agriculture based on *milpa* systems – mixed cropping systems combining maize, beans, and squash, among others – including distribution and consumption based on reciprocity patterns. Official risk assessments emphasize drought as well as inundations, deforestation, and soil and water contamination (Gobierno Autónomo Municipal de San Pedro, 2013; Gobierno Autónomo Municipal de Samaipata, 2016). In a study on risk perceptions, we noted that most risks referred to the production level (pests and diseases, contamination, drought) (Jacobi et al., unpublished). At the same time, several of the food system actors viewed their involvement in these mechanisms as only temporary, and therefore few had transformative ambitions within the agroindustrial food system. By contrast, actors from an alternative food system perceived a multi-pronged food, environmental, socio-cultural, and economic crisis that demanded collective action in response. Their main perceived risks were weak economic involvement and lack of recognition by public authorities (ibid.)..

In Kenya**,** we selected the counties of Meru and Laikipia in the northwestern Mt. Kenya region. Here, intensive horticulture farms employ farmworkers, many of whom also grow various crops and keep livestock as smallholders. These two different food system contexts concentrate around the humid slopes of Mount Kenya and – similar to the two Bolivian examples – are linked to local, national, and global markets. Horticultural companies produce cash crops (e.g., runner beans, broccoli, and leafy vegetables). Smallholder farmers produce food crops both for household consumption and for sale (e.g., maize, beans, pulses, potatoes, tomatoes, and onions); and livestock products (e.g., dairy and meat from cattle, goats, and camels). The two food systems compete for labour and natural resources, with water access particularly contested. Risks to food systems in the northwestern Mount Kenya region include, in particular, droughts (often followed by floods), water and land use conflicts, human–wildlife conflicts, pests, and diseases (Ministry of Environment and Natural Resources, 2016). In a study on local perceptions regarding food, people strongly perceived impacts from pesticides and unhealthy diets as a risk from production and consumption (Hertkorn, 2016). Following Colonna et al. (2013), who distinguish between agroindustrial, regional, local, domestic, and differentiated-quality food systems, we selected three different types of food systems as social-ecological systems for resilience assessment (Cumming et al., 2005): Two *agroindustrial* food systems, one in Kenya, and one in Bolivia; an *agroecological (differentiated-quality)* food system in Bolivia; and a *local* food system in Kenya (Table 2).

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Table 2

Food systems / case studies: Main features and key actors. Based on Colonna et al. (2013) and Jacobi et al. (unpublished).

Food system	Place	Main features	Key actors[a]
Bolivia: Agroindustrial food system	Santa Cruz Department, Municipality of San Pedro	Mainly soybeans, sometimes in rotation with food grains; sugar cane; 3% of producers cultivate 56% of the land. Production and initial processing in Santa Cruz Department, Bolivia. Trade and consumption of soybeans: >70% of soy beans are exported; six companies organize most of soy bean exports (McKay and Colque, 2015)	Transnational companies (seeds and agrochemicals, machinery, silos and processing facilities); social organizations (e.g., confederation of syndicates of rural workers CSUTCB, National Confederation of Peasant Women Bartolina Sisa); state enterprise EMAPA; Bolivian Institute of Foreign Trade IBCE; Association of oilseed growers ANAPO; NGOs (e.g., Fundación Tierra, Probioma, and FIDES) municipal governments, departmental and central government
Bolivia: Agroecological food system	Santa Cruz Department, Municipality of Samaipata, city of Santa Cruz	"Agroecological Platform": Network of producers and consumers; own identity label, mutual low-cost certification. Regular farmer's markets in the city of Santa Cruz; direct trade relations; value chains within the rural-urban continuum of Santa Cruz	Agroecological farms (e.g., Fundación Patiño, El Sauce, La Víspera), National Council on Ecological Production, small shops (Naturalia, La Tiendita Natural), some supermarkets, restaurants e.g. La Casona; NGOs Probioma, Slow Food Bolivia, and Heifer international
Kenya: Agroindustrial food system	Northwest Mt. Kenya region, Laikipia County	Horticultural farms producing leafy vegetables, runner beans, French beans, and broccoli for European markets mainly in northern-hemisphere winter. Production, processing, and packaging on-farm; transport and export organized by export firms; extension services by input-providing companies	Transnational companies; horticultural farms (e.g. AAA); Kenya Horticulture Crops Development Authority; Fresh Produce Exporters Association; Africa Freight Handlers, Kuhne, Nagel Logistics; export standards (e.g. Global Gap); Kenya Plant Health Inspectorate Service; Kenya Bureau of Standards, Supermarkets in Europe (e.g., Tesco)
Kenya: Local food system	Northwest Mt. Kenya region, Laikipia and Meru Counties	Smallholder households (ca. 0.5-3 ha) who produce both for local markets and for subsistence; involving maize, potatoes, fruits, vegetables, livestock including milk production, and more	Local households and small farms in Laikipia and Meru Counties; inputs stores, Syngenta Foundation for Sustainable Agriculture; Kilimo Biashara; Caritas; farmers markets and small shops in and around Nanyuki, Timau and Meru; County-specific Agricultural Sector Support Programmes

[a]Food system actors addressed in the framework of the present study were (1) those identified by our local research partners as important to the food system, and (2) those identified in a participatory food system mapping activity (Jacobi et al., in press).

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2.4 Field methods and data analysis

In all four food systems, we engaged with different value-chain actors, which we had previously identified using a participatory food system mapping approach (Jacobi et al., in press). Then we selected 2–3 individual or organizational actors for each stage of the most important value chains whom we interviewed about the resilience aspects specified in Tables 1a, 1b, and 1c. Since this study was part of a larger, interdisciplinary research project, different researchers contributed data to it, as specified in Table 3.

In Bolivia, we conducted 29 guided interviews on the resilience dimensions of self-organization and capacity for learning/adaptation with the following actors: input suppliers, farmers, NGOs, politicians, seed companies, agrochemical companies, machinery makers/vendors, exporters, retailers, restaurants, and consumers. We conducted participant observation on seven occasions where different food system actors came together (one fair on soybean production in the town of Cuatro Cañadas, three agroecological Fairs in Santa Cruz de la Sierra, one assembly of the Agroecological Platform, and two political advocacy events in La Paz). Agrobiodiversity and landscape diversity were evaluated in two individual research studies, namely Catacora-Vargas (2016) and Augstburger (unpublished). Data on the resilience dimension of buffer capacity were derived from a livelihoods survey of 136 purposefully selected individuals (86 in the agroindustrial and 50 in the agroecological food system, Table 3 lists them broken down according to stages in the food value chain (production to consumption).

In Kenya, we conducted 57 guided interviews on the resilience dimensions of self-organization and capacity for learning/adaptation with the following actors: smallholders, large-scale farmers, local market vendors, other retailers, wholesalers, restaurants, and NGOs. Further, we held a focus group discussion with a local women's group in Muramati village in Laikipia East. Data on the resilience dimension of buffer capacity (Table 3) were provided by an agrobiodiversity study (Wakuyu unpublished), a landscape diversity study (Augstburger, unpublished), and a livelihoods survey with 530 randomly selected local households in six villages in the Mt. Kenya region (Mutea, unpublished). We transcribed interview recordings, videos, and notes and codified the resulting texts according to the specified indicators using Atlas.ti (Version Win 5.0). We scored the results for each indicator according to criteria that we previously co-developed with local researchers from the project team (Table 1a, 1b, and 1c). For the joint scoring process, we organized one workshop in Bolivia and one in Kenya with 15 participants on average. We used an ordinal Likert scale from 0–4 that combines qualitative and quantitative data ("nothing" to "very high"; "undesirable" to desirable"; and percentages). All indicators were weighted equally, since different food system actors had different priorities, and we were not in a position to decide which were more or less important. We averaged the scores of the indicators for each resilience dimension in each food system in order to generate an overview, remaining aware that such aggregation of partly qualitative data only allows for limited conclusions.

Table 3

Methods used to assess resilience indicators of food systems in Kenya and Bolivia

Method	Kenya	Bolivia
Participatory food system mapping[a]	One week field study mapping the 2–3 most important value chains in both food systems	One week field study mapping the 2–3 most important value chains in both food systems

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Livelihoods survey	530 surveys with randomly selected local households[b]	136 surveys with local households, selected to represent different activities in the food system (10 input providers, 48 producers, 10 involved in transport; 3 middlemen, 13 processing actors; 10 retailers; 42 consumers[c])
Agrobiodiversity study	List of crop and breed diversity from 78 farms (6 agroindustrial, 72 smallholder farms)[d]	List of crop and breed diversity from 19 farms (10 agroindustrial farms and 9 agroecological farms)[e]
Landscape diversity	Mapping of different land-cover classes on 6 farms[f]	Mapping of different land-cover classes on 6 farms[f]
Interviews (open-ended interview guide) on self-organization, and on the capacity for learning and adaptation[g]	57 interviews: 25 smallholders; 5 managers of horticultural companies; 5 retailers/middlemen, 3 wholesalers, and 5 restaurants; 14 organizations that deal with resilience building and risk mitigation (NGOs, a nutritional health expert, representatives of the national and county governments of Laikipia and Meru, relevant ministries, and research organizations)	29 interviews: 7 input suppliers, 6 producers, 3 processing actors, 4 retailers, 2 consumers, and 7 actors who provided analysis and advice (NGOs and policymakers)
Focus group discussion	Women's group, Muramati village	
Participant observation	Relevant government institutions at the county and national level as well as relevant non-governmental organizations (NGOs)	1 fair and 2 political advocacy events in the agroindustrial food system; 3 fairs and 1 assembly in the agroecological food system

[a]Jacobi et al., in press; [b]Mutea et al., unpublished; [c]Catacora Vargas, 2017; [d]Wakuyu, unpublished [e] Catacora Vargas 2016; [f]Augstburger, unpublished; [g]for interview contents see Tables 1b and 1c.

3 Results

In the following, we present the most important findings from our indicator-based assessment of each dimension of our social-ecological resilience indicator framework. The assessment results for Kenya and Bolivia are described separately because direct comparison of the indicators might be misleading due to a certain degree of adaptation and contextualization of the methods in either country. However, we have identified several common cross-country patterns that are described in section 4.1.

3.1 Buffer Capacity - Kenya

The agroindustrial food system had a higher **buffer capacity** (2.9) than the local food system (2.3) (Fig. 1). We found higher values for physical capital – and, to a lesser extent, for financial capital, social capital, natural capital, and human capital – in the agroindustrial food system. On the other hand the local food system displayed high diversity of crops and breeds as well as high physical capital (due to inclusion of livestock in this indicator based on DFID, 1999). The lowest buffer capacity values identified were for diversity of crops and breeds in the agroindustrial food system, and for natural capital in the local food system. On average, both food systems had a medium to high buffer capacity, though this masks considerable differences between them, which the livelihoods survey helped us identify. Natural capital was medium in the agroindustrial food system, and low in the local food system: producers in the agroindustrial food system had

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an average of 90 ha of land while farmers in the local food system had to make due with less than 2 ha of land on average, but displayed better soil management. Natural capital depended, among other things, on social capital. For example, the bargaining power of horticultural farms was stronger than that of smallholder farmers in the local food system, and this bargaining power was the most important determinant of access to river water – a key natural resource for both food systems. Whereas overall financial capital was high in the agroindustrial food system, medium scores were identified regarding wage levels in the agroindustrial as well as in the local food system. There were major differences between actors within the food systems: In the agroindustrial food system, supermarkets in the global North captured 68% of the profit generated along the value chain for exported green beans (Teuscher, 2017). However, horticultural farms provided local jobs as well as non-monetary benefits to workers, such as free transportation to work, supplementing the minimum wage. In the agroindustrial food system, monthly per capita wages paid to workers hovered near the minimum wage (KES 6,780/USD 66 for skilled workers; KES 5,436/USD 53 for unskilled workers), whereas monthly incomes from farming activities in the local food system were KES 8,020/USD 79 on average, plus irregular incomes from livestock keeping. In 5% of the households surveyed, at least one household member had worked on a horticultural farm in the previous 12 months; and in another 12% of households, at least one household member had worked as an outgrower. In contrast to the agroindustrial food system, farmers in the local food system had difficulty obtaining access to machinery (part of physical capital), and instead relied mainly on hand tools.

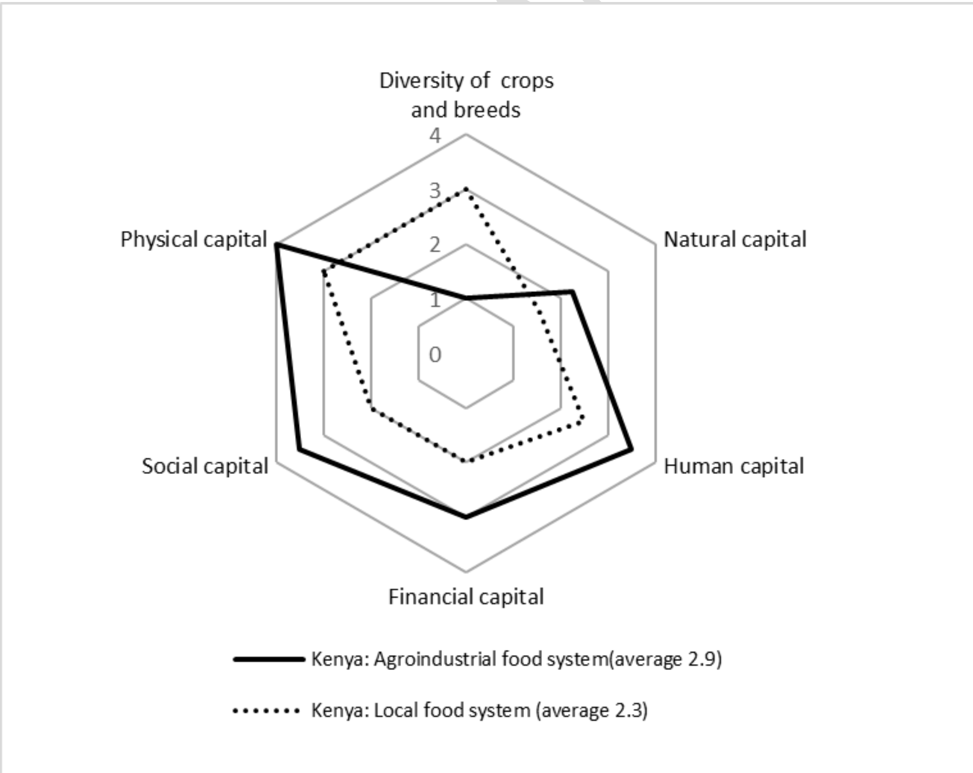

Fig. 1. Buffer capacity indicators rated for an agroindustrial and a local subsistence-based food system in Kenya from 0 (null) to 4 (very high)

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3.2 Self-organization - Kenya

Regarding the resilience dimension of **self-organization**, both the local and the agroindustrial food system exhibited a medium-to-high overall score (2.7) (Fig. 2). The local food system scored very high for local consumption of production (78% of production). The agroindustrial food system scored high for decentralization and independence due to direct trade relationships (European supermarkets procuring directly from horticultural farms) and diversified input sources – most of them external, but some local. The local food system was dominated by middlemen and thus displayed only medium scores. The agroindustrial food system scored highly regarding interest groups. Both the agroindustrial and the local food system scored highly for ecological self-regulation (for details, see below). The lowest scores identified pertained to local consumption of production in the agroindustrial food system. Connectivity was medium-high in the agroindustrial food system, and medium in the local food system. Indeed, both food systems featured connectivity, but of different kinds: Kin and local support were central mechanisms of cooperation in the local food system (e.g., support within family networks with institutional settings, local self-help groups with their own institutions/bylaws). Vertical integration and interaction with other food systems produced strong connectivity in the agroindustrial food system, but it was tempered by low bargaining power in the social capital of farm workers and small-scale outgrower farmers. In the milk value chain of the local food system, actors at the processing stage had the most bargaining power and made the highest profits. Milk was mainly produced by smallholder farmers. Some smallholders belonged to cooperatives and sought to reduce their dependence on the many middlemen who collected the milk from farmers and transported it to cooling plants/processing plants. Both food systems had their own interest groups specific to the products and food system activities. The percentage of farmers organized in groups was 90% for the agroindustrial food system. Among the sample of smallholders, only 48% belonged to interest groups. The organization of farmers in Water Resource User Associations proved helpful for soil and water management in both food systems, especially by improving water availability in the dryer lowlands (though weak actors remained excluded from water access) and planting trees together with the Kenya Forest Services and Community Forest Associations. In terms of ecological self-regulation, landscape diversity on horticultural farms was high, since relatively small spaces were used intensively; by law, 10% of any landholding must be covered by trees, and integrated pest management techniques included use of vegetation strips for insects, for example. Landscapes of the agroindustrial food system were diverse, but dominated by greenhouses, while landscapes of the local food system were highly diversified including multifunctional trees such as *Grevillea robusta*.

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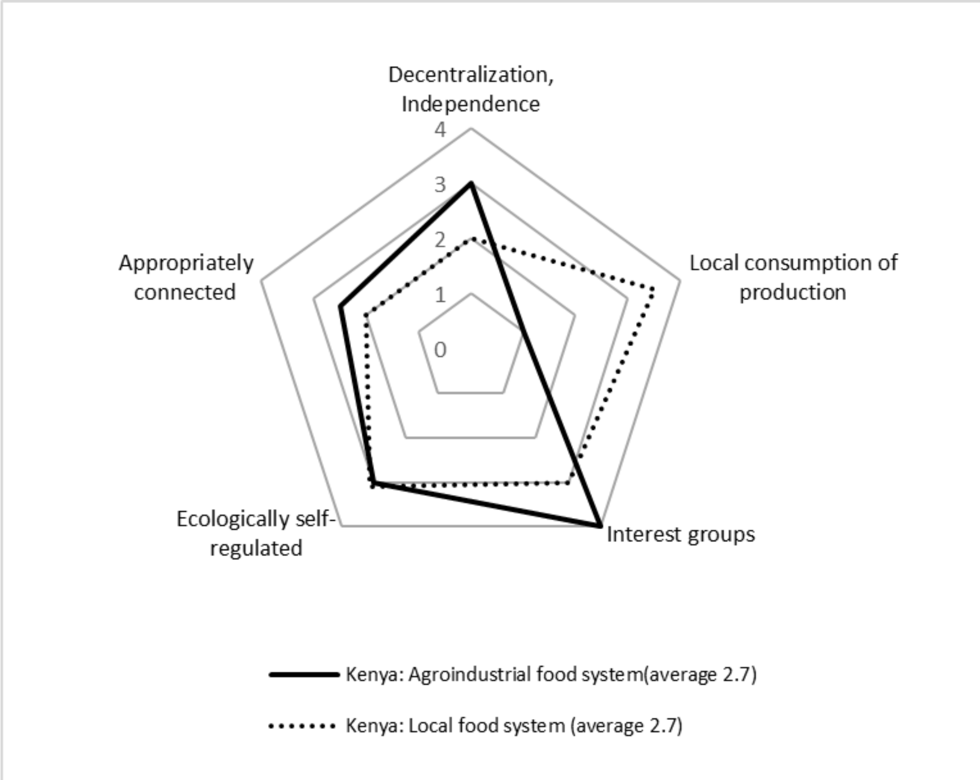

Fig. 2. Self-organization indicators rated for an agroindustrial and a local subsistence-based food system in Kenya from 0 (null) to 4 (very high)

3.3 Capacity for Learning and Adaptation - Kenya

In Kenya, the highest aggregate score for the dimension **capacity for learning and adaptation** was displayed by the agroindustrial food system (2.8), while the local food system had a slightly lower aggregate score of 2.7 (Fig. 3). The highest individual indicator scores were for knowledge of threats and opportunities and functioning feedback mechanisms in the agroindustrial food system. The local food system also scored highly for knowledge of threats and opportunities, as well as for functioning feedback mechanisms and existence and use of local-traditional knowledge. The single lowest score was found in the agroindustrial food system for (lack of) existence and use of local-traditional knowledge. Regarding threats and opportunities, product standards were repeatedly mentioned. The Kenya Plant Health Inspectorate Service (KEPHIS) operated an elaborate warehouse at the produce shipping point, where vegetables were checked for adherence to market standards of sanitation and product quality. Any products not meeting the standards were rejected without compensation, which, according to the producers, encouraged increasing use of agrochemicals. Reflective and shared learning was high in the agroindustrial food system due to high numbers of workshops for workers at all levels, and medium-to-high in the local food system. Efforts towards shared learning were evident in both food systems. Private-sector support predominated (e.g., Syngenta Foundation for Sustainable Agriculture in the local food system), and some large farms offered extension services to small-scale farmers. One technical advisor stated: "*We do not depend on the company. But whenever there is a new product, we go to the field and inform the farmers about it*" (representative, Syngenta Foundation, Nanyuki, October 2015). Research organizations such as the Kenya

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Agricultural & Livestock Research Organization (KALRO), International Maize and Wheat Improvement Center (CYMMIT), and regulators such as KEPHIS and the Kenya Dairy Board were instrumental in promoting knowledge in both food systems. Kenya Cooperative Creameries featured a training unit that advised farmers on good animal husbandry practices to increase milk production. Potato farmers in the local food system received support from the National Potato Council of Kenya to improve productivity and enhance access to markets and storage. The feedback mechanisms in the agroindustrial food system were tied to well-functioning support mechanisms, mainly governed by actors in the private sector and parastatal organizations like KEPHIS acting in accordance with economic incentives and standards such as GlobalGAP originating in the retail destinations (predominantly Europe). Except for the registration of groups and witnessing of contracts by Kenya's Horticulture Crops Development Authority, the government appeared to play a subordinate role in the export-oriented horticulture sector. Actors in the local food system exhibited some degree of functioning feedback mechanisms, but not as elaborate or comprehensive as those in the agroindustrial food system. The local food system performed well regarding use of local knowledge, whereas the agroindustrial food system scored low in this category of resilience due to its focus on production of non-traditional crops such as broccoli, and encouragement of consuming non-traditional foods like white bread and ready-made cakes. Another recent study (Hertkorn, 2017) on local perceptions of "good food" found that (especially elderly) interviewees perceived increasing consumption of food high in sugar, saturated fats, and white flour; the respondents referred to it as "*food that is not strong for the body*", in contrast to their traditional foods that they described as "*food that gives you strength*". No clear, shared food system vision was identified among actors in either of the food systems we studied in Kenya.

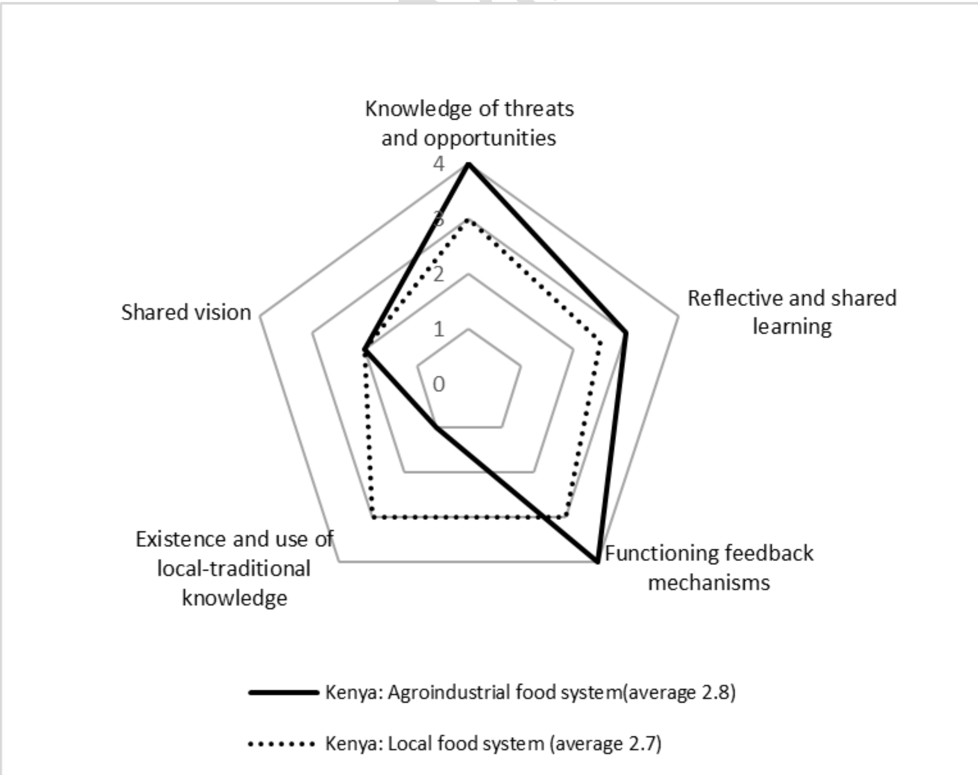

Fig. 3. Capacity for learning and adaptation indicators rated for an agroindustrial and a local subsistence-based food system in Kenya from 0 (null) to 4 (very high)

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3.4 Buffer Capacity - Bolivia

Among the food systems in Bolivia, the agroecological food system exhibited a medium-to-high aggregate **buffer capacity** (2.7), while that of the agroindustrial food system was low-to-medium (1.8) (Fig. 4). However, the agroindustrial food system exhibited the highest level of physical capital and financial capital. In contrast, the agroecological food system was high in natural capital and human capital. The lowest score in this resilience dimension was found for diversity of crops and breeds in the agroindustrial food system. However, the average diversity of crops and breeds was also rather low on average in the agroecological food system, with the exception of three farms that had more than 30 different crops and breeds (Catacora Vargas, 2016). The agroindustrial food system displayed low buffer capacity, not only in terms of diversity of crops and breeds, but also regarding natural and social capital. By contrast, the agroecological food system only scored low-to-medium for social capital, scored above medium for diversity, and almost medium for social capital. For the soybean sector (the most important value chain within the agroindustrial food system), our actor analysis revealed the need to further differentiate buffer capacity according to three types of land users/farms – i.e., smallholders (<50 ha), medium-scale farms (51–500 ha), and large-scale farms (>500 ha) – according to the locally used classification. Based on our livelihoods survey, we identified major disparities in financial capital between large-scale farmers and smallholders: Large-scale farmers earned more than 400 times as much as small farmers, and had profit margins approximately 250% higher per hectare of soybean (USD 141 per ha per crop for smallholders, and USD 353 per ha per crop for medium- and large-scale farmers). Elsewhere on the soybean value chain, incomes were relatively equal – increasing slightly among retailers. The one remaining exception was input providers' (vendors of seeds, pesticides, and fertilizers) average monthly incomes, which were 220% higher than the average of other value chain actors. Average monthly wages along the value chain were similar in the agroindustrial (BOB 3,875/USD 549) and the agroecological food system (BOB 4,000/USD 567), though with large disparities especially between different actors such as small-scale farmers and large-scale farmers, as mentioned before.

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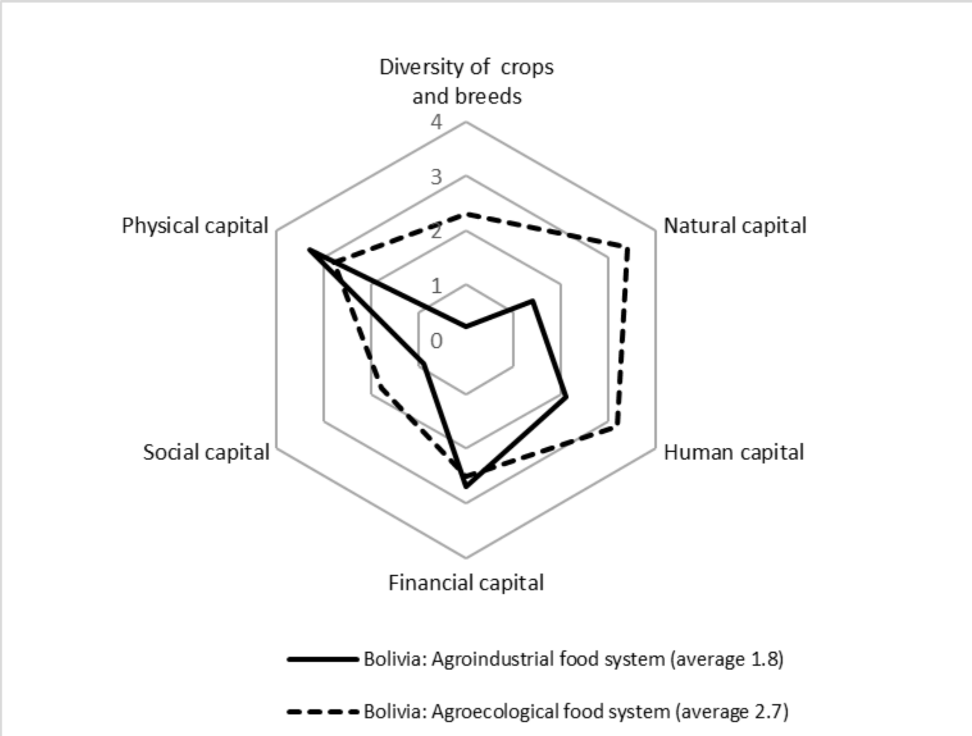

Fig. 4. Buffer capacity indicators rated for an agroindustrial and an agroecological food system in Bolivia from 0 (null) to 4 (very high)

3.5 Self-organization - Bolivia

As for **self-organization** in Bolivia, the agroindustrial food system had a rather low average (1.6), but displayed a prominent peak in interest groups (Fig. 5). By contrast, ecological self-regulation was very low. Furthermore, this food system scored close to zero regarding local consumption of production. Decentralization and independence were also very low in the agroindustrial food system, due to stakeholder dependence on external seeds and other inputs, and low in the agroecological food system, due to poorly developed market chains (for instance, there were few points of sale). Indeed, in contrast to our findings in Kenya, decentralization and independence were weak among both food systems in Bolivia. In the agroindustrial food system, interest groups were particularly strong because of their robust vertical organization across food system levels, and because the food system was locally, nationally, and globally integrated – from input providers to transnational actors in storage and wholesale (see McKay and Colque, 2015). The agroecological food system was more horizontally organized based on its producer–consumer network, the Agroecological Platform, featuring direct trade relations, with decisions made locally and all affiliated members on an equal footing. Connectivity was medium-to-high in the two food systems. Various strengths and weaknesses were combined to arrive at the medium scores: The agroindustrial food system was highly organized and featured many collaborative connections. However, certain actors involved – in particular small-scale producers – did not share in the profits, and were deprived of participation in decision-making. Further, trust was low between the different food system stages, e.g., soybean farmers and silo-owning companies who purchased their yield. The disconnection even included the municipal government of San Pedro: "*We cannot access the large-scale soybean farms in the municipality to verify whether environmental laws are being respected. They do not allow us enter*" (head of

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the environment and natural resources management division, San Pedro municipality, August 2016).

Finally, the agroecological food system featured many collaborative connections and high levels of trust within the food system network. However, a related anthropological study found that resource-poor producers and consumers had difficulty accessing this food system's products and markets (Schälle, 2017). Further, it was ideologically disconnected from other important groups such as the National Confederation of Peasant Women (known as Bartolinas). This latter group declared agroecology as their basic concept, yet demanded land from the central government for the paradoxical purpose of agroindustrial soybean production. In the interview, their departmental leader stated:

"*We are 6,367 members in the department, all small-scale producers. Only 30% of the women have a land title document with their name on it. We demand land for groups of us. The largest [available] lands are in the Chaco region. There we can spray pesticides on those crops that we sell, while avoiding spraying close to our homes and on the crops that we* eat."

Later, the same interviewee affirmed:

"*We want to have a closer link to La Vía Campesina, we want to aspire to their vision, but we are still far away*" (departmental representative, Bartolinas, Santa Cruz de la Sierra).

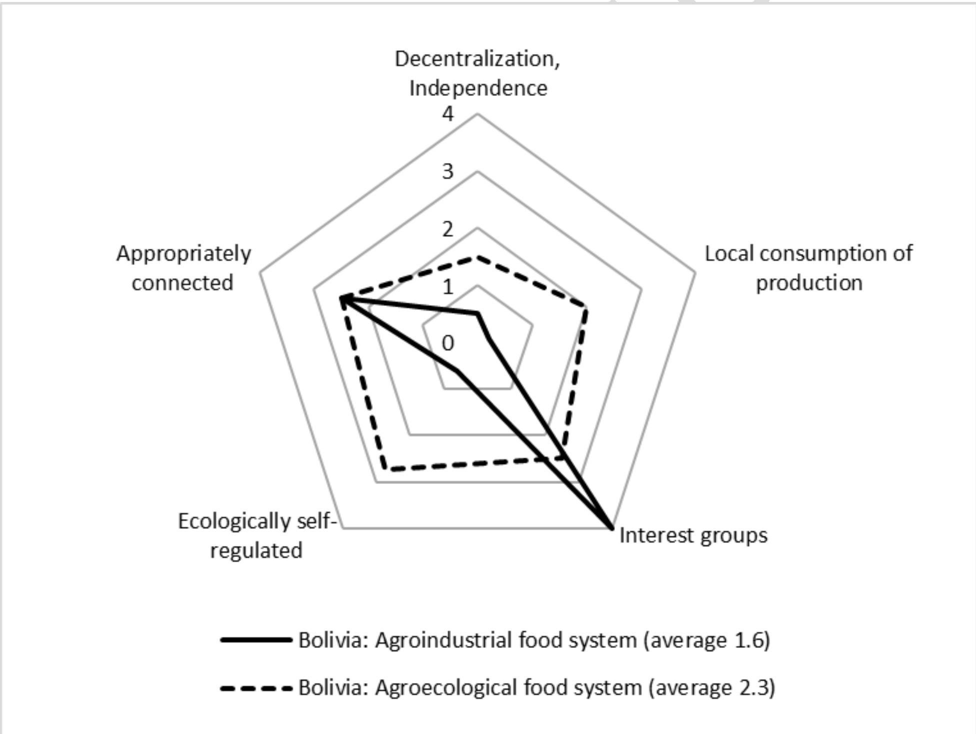

Fig. 5. Self-organization indicators rated for an agroindustrial and an agroecological food system in Bolivia from 0 (null) to 4 (very high)

3.6 Capacity for Learning and Adaptation - Bolivia

The highest overall score for the dimension **capacity for learning and adaptation** was exhibited by the agroindustrial food system (3.3) (Fig. 6). However, this food system also displayed the lowest individual indicator score – i.e. for local-traditional knowledge. The highest individual indicator scores identified were for the shared vision of different actors in both the

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agroindustrial and the agroecological food systems. Other very high scores in the agroindustrial food system were: knowledge of threats and opportunities, reflective and shared learning, and functioning feedback mechanisms. Besides displaying a strong shared vision of agroecology, the agroecological food system exhibited high scores for functioning feedback mechanisms and knowledge of threats and opportunities. The agroindustrial food system ranked very high for all indicators except local-traditional knowledge. The high scores derive from its strong vertical integration and the connectivity of relevant actors at every level. Substantial differences were found between the two food systems with respect to learning: high in the agroindustrial food system, and medium-to-high in the agroecological food system. Numerous actors were engaged in reflective and shared learning in the agroindustrial food system: In the municipality of San Pedro, the most accessible learning activities were private-sector agricultural extension services, such as those offered by Agripac of Syngenta or by Ciagro working with Bayer:

"We [Agripac] have 12 agencies and two demonstration centers, one in San Pedro and one in Cuatro Cañadas. We have five regional offices, and we organize capacity-building activities all the time. In February alone, we had 12 events in Santa Cruz: Six technical talks, three field days, and three technical tours" (Agripac representative, Santa Cruz de la Sierra, April 2016).

On a much smaller scale, women's groups provided workshops and visited schools to promote healthier diets in and around the city of Santa Cruz, and producers exchanged adaptation strategies particularly regarding irrigation technology (Mukhovi et al., unpublished). In the agroecological food system, organizations linked to the network of the Agroecological Platform offered cooking courses encompassing organized projects on tending kitchen gardens in soybean-industry areas. We witnessed events in the urban gastronomy sector by youth groups promoting "conscious food", or *Comida Consciente*, a movement underway in different Bolivian cities. Other evidence of learning occurring through local food movements was provided by the emergence of organizations such as Slow Food Bolivia, Selva Sabrosa, Manq'a schools educating chefs on the outskirts of several Bolivian cities, and the Bolivian Movement of Gastronomic Integration (MIGA), which seek to promote food that is local, healthy, and fresh.

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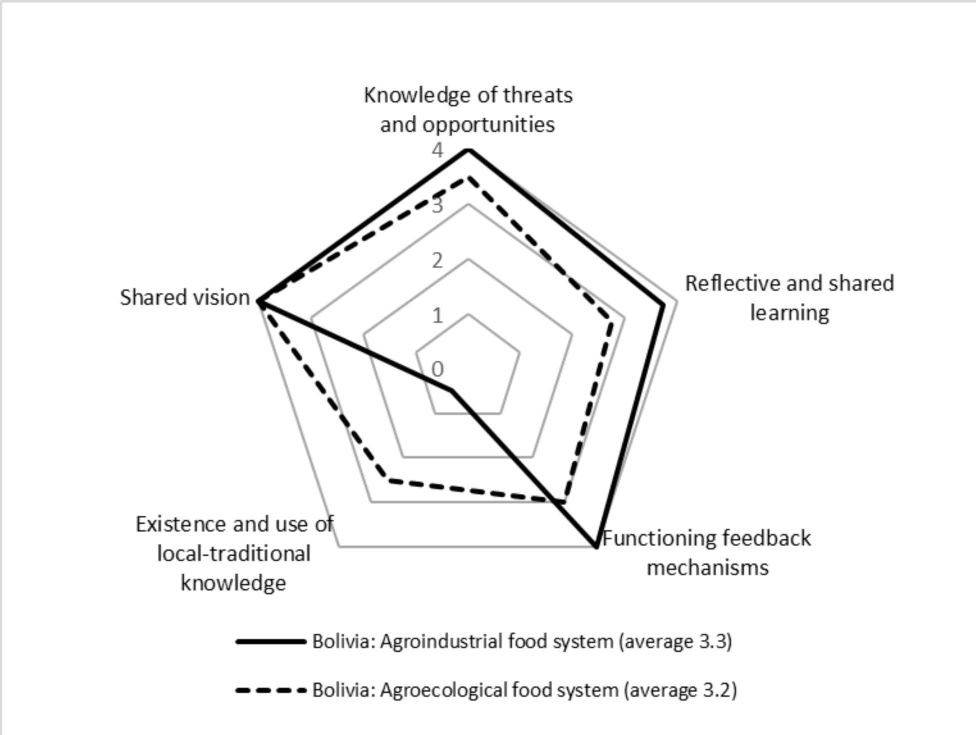

Fig. 6. Capacity for learning and adaptation indicators rated for an agroindustrial and an agroecological food system in Bolivia from 0 (null) to 4 (very high)

4 Discussion

4.1 Trends contributing to lower or higher resilience in the food system case studies

The agroindustrial food systems in Kenya and in Bolivia were both high in physical capital, relatively strong regarding financial capital, very high in knowledge about threats and opportunities, well-organized according to interest groups, strong regarding learning, and displayed functioning feedback mechanisms (the latter especially regarding institutional support, e.g., KEPHIS in Kenya). Overall, they exhibited the highest capacity for learning and adaptation of all the food systems. Similar properties have been described by IPES-Food (2016) and Blesh and Wittman (2015). However, the two agroindustrial food systems in Kenya and Bolivia occurred side by side with other food systems, and significant disparities were found, for example, between large-scale and small-scale farmers operating within the coexisting systems (see 3.1 and 3.4). These disparities must be considered vis-à-vis the apparent strengths of the agroindustrial systems. The disparities found regarding key livelihood assets (e.g. financial capital in terms of incomes, and natural capital in terms of access to land) pointed to asymmetries in bargaining power between agricultural investors and small-scale farmers in Kenya; actors at the producing/processing stage and retailing stage in Kenya; and large and small soybean farmers in Bolivia. These asymmetries were also reflected in differences in the number of interest groups and their outreach, and in reported decision-making autonomy. Further, the existence and use of local knowledge was low in the agroindustrial food systems (see 3.3 and 3.6), as was their contribution to local food security (see 3.2 and 3.5). On the latter point, food production was increasingly a function of the demands of distant markets, not the food needs of local people (De Schutter, 2014). In particular, the agroindustrial food system in Bolivia gave

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rise to homogeneous landscapes (see 3.4 and 3.5), reducing local buffer capacity in terms of crop and breed diversity and ecological self-regulation. Moreover, the resilience of the agroindustrial food system in Bolivia appeared to be declining within the production stage, as indicated for instance by record losses of yields and investments during the 2016 drought (La Razón, 2016), a development that should be closely monitored. In addition, the contribution of export-oriented agroindustrial food systems to local livelihoods was not as high as expected: In Kenya, wages in the agroindustrial food system (see 3.1) were lower than farm incomes in the local food system, contradicting earlier studies on export-oriented farms in Kenya (Van den Broeck and Maertens, 2016). Our representative livelihood study reinforced this finding, pointing to rather low involvement of local households in the production stage of horticultural farms – whether as labourers or as outgrowers – and even less involvement in other stages of related horticultural value chains (see 3.1 and Ulrich et al., 2012). Short-term contracts and possible health impacts should be included in future assessments of the impacts of agroindustrial farms on local livelihoods. Meanwhile, in our Latin American study setting, large-scale soybean producers in Bolivia reported employing no more than two agronomists per 500 ha. Furthermore, the potential economic benefits of agroindustrial food systems were accompanied by negative social-ecological externalities. These externalities included deforestation, which had increased in Bolivia by 183% between 2015 and 2016 (Global Forest Watch, 2017) – especially due to soybean growing (Fehlenberg et al., 2017). Additionally, growing concentration of land ownership was a perceptible social externality (Urioste, 2012; McKay, 2017). In Kenya, negative externalities included competition over water resources and salaries too low to cover people's basic needs (Ulrich, 2014). The agroindustrial food system in Kenya had a high carbon footprint based on use of machinery, inputs, cold chain and air transport of the fresh vegetables to Europe; it was also less energy-efficient than the local food system, and produced more non-reusable waste (e.g., packaging) (Ottiger, 2018). Finally, both food systems in Kenya and the agroindustrial food system in Bolivia displayed high use of toxic agrochemicals – including pesticides that were forbidden in the respective countries (Bascopé, unpublished; Ottiger, 2018). Although certified based on international standards such as GlobalGAP, the agroindustrial food system in Kenya used about six times the quantity of pesticides per unit area in comparison with the local food system (Ottiger, 2018).

Our results also show that interactions between food systems can increase their buffer capacity. During the 2016 drought in Bolivia, for example, we observed that by-products from large-scale sugarcane production were transported from the agroindustrial food system in the San Pedro Municipality to the dryer Chaco region in the south, saving livestock from starvation in the latter location. In Kenya, by contrast, interviewees described how livestock starved in large numbers during the drought in 2016, as there was no comparable coping mechanism regarding use of agricultural by-products from the agroindustrial food system. However, during long dry spells, smallholders reported occasionally obtaining water from agroindustrial farms, and local farmers sometimes allowed pastoralists to graze animals on their land.

Food system interactions can also lower resilience, however. This was seen in the case of smallholder farmers in Bolivia who began producing for agroindustrial value chains. These smallholder farmers compete with farmers who have 10–100 times more land and associated machinery, besides being officially or unofficially bound to input-providing and/or processing companies. At the same time, the smallholder farmers rely on predominantly informal institutions for support, and they possess lower natural, financial, and physical capital. McKay

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and Colque (2015) observed increasing "productive exclusion" of smallholders in soybean-growing areas of Bolivia. This indicates that other production systems and livelihoods are being absorbed by the soy system, but the rules of the game – and the associated profit distribution within the value chain – benefit large-scale farmers and associated actors (e.g., related to soy storage and processing). In the neighboring soy sector of Cuatro Cañadas, Hirsig and Märki (2016) observed the same phenomenon. Choice is further limited by the related structures of input suppliers, buyers, and modes of production. For example, the prevalence of aerial spraying of herbicides precludes cultivation of anything other than herbicide-resistant plants. Tensions around aerial spraying were also observed in Laikipia between farmers in the local food system versus agroindustrial farms: Small-scale farmers in our interviews reported that the expansive nature of cereal farms resulted in spraying from aircrafts, which, according to them, contaminated their crops and the environment in general. They also complained about white flies and caterpillars affecting their crops, whose source according to them were agroindustrial horticultural farms. Zähringer et al. (2018) reported similar local perceptions, including pesticide drift from horticulture and floriculture farms affecting human health and the natural environment.

Against this background, the spatial and economic expansion of the two agroindustrial food systems may bear social-ecological risks for food sustainability in both study regions in Bolivia and Kenya. Further, increasing *linkages* between agroindustrial food systems and local, as well as agroecological food systems could exacerbate the resilience-reducing externalities of agroindustrial food systems, as these externalities begin to play a role in other types of food systems as well. The linkages and related impacts we observed encompass the following: *input provision*, including increasing use of imported seeds, pesticides, fertilizers, and machinery; *production techniques*, including loss of locally adapted crops and associated knowledge; *storage and processing methods*, in which agroindustrial infrastructure dominates, marginalizing weaker actors and the diversity of food products; and *consumption dynamics*, including growing dependence on powerful food distribution actors (e.g., supermarkets, see 3.1 and 3.2) who define the terms of trade for both producers and consumers. These patterns suggest that factors of decreasing resilience within agroindustrial food systems could also negatively impact other food systems. However, there are several leverage points that may be used to support necessary transformation and address specific issues across food systems.

4.2 Leverage points and potentials to build resilience

With respect to the disparities identified between actors operating within export-oriented agroindustrial food systems, the livelihood assets of marginalized actors must be improved. In other words, it is necessary to increase the financial, human, social, natural, and physical capital of smallholder farmers in soybean-production areas, for example. This implies challenging prevalent production modes, value chains, and related power relations, replacing concentrated bundles of power with more widely shared bundles of power and rights (Ribot and Peluso, 2003). One major constraint in Bolivia is that marginalized food system actors often remain unaware of their rights and/or are not able to assure access to the juridical system (Gonzales Soto, 2016). Therefore, marginalized actors cannot really build momentum to push the state towards more efficient levels of compliance with existing laws and regulations.

Regarding the identified vulnerability factors of agroindustrial food systems, in a previous study (Jacobi et al., unpublished) we found that many actors in these food systems are aware of the

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environmental and economic risks, but few of them are able to change or adapt their behavior appropriately in response. Analyzing the vulnerability factors of food systems, Eakin (2010) found that large spatial distances between production and consumption points made food systems prone to disruption from environmental and socio-economic shocks. In our study areas, environmental regulations – e.g., 10% forest cover requirements on farms in Kenya or mandatory forest strips as windbreaks on farms in Bolivia – often were not properly enforced. Where buffer capacity and self-organization are too weak to address environmental degradation or related power asymmetries (see 3.5), enabling conditions for local bottom-up institution building are needed, including addressing power differences (see Haller et al., 2015; Walsh-Dilley et al., 2016).

In our case studies, it was mainly actors from the agroindustrial food systems who organized learning and information sharing, thus reinforcing their mechanisms. In both agroindustrial food systems we studied, learning and information sharing were arranged by technical advisors employed by companies selling agricultural inputs (in our sample, specifically, Bayer, Syngenta, and others in Bolivia, and the Syngenta Foundation for Sustainable Agriculture in Kenya). However, small-scale farmers in particular lacked access to capacity-building interventions tailored to their needs, thus constraining their freedom of choice. For example, private-sector development projects in the northwestern Mt. Kenya region steered smallholder farmers to engage in outgrower schemes, encouraging them to give up food production for local markets in favor of export crops. Overall, learning opportunities and support mechanisms were virtually absent regarding *non*-agroindustrial food systems. The local food system around Mt. Kenya was characterized by a low degree of self-organization among farmers and a high number of middlemen in the value chain. Nevertheless, farmers in this food system easily grew more than 20 different crops on half a hectare of land, covering most of their family's consumption needs with their own production (Wakuyu, unpublished). Relatedly, Niggli et al. (2016) found that only 0.6% of worldwide annual funding for research and extension is directed towards research on organic food and farming systems. This number may be even lower if traditional and agroecological food systems are included in the calculation. Based on their food system sustainability research project, Esnouf et al. (2013) concluded that traditional, local food systems remain the main food supply source in the global South (see also Samberg et al., 2016). Such food systems have built up resilience to instabilities over long periods, standing the sustainability test of time (Altieri and Koohafkan, 2008). For example, indigenous food systems such as the food system of the Guaraní people in the study area in Bolivia (Jacobi et al., unpublished) has developed resilience over centuries, based on production of their own food, associated knowledge and agrobiodiversity, reciprocity mechanisms, and independence. These factors may not cushion sufficiently against immediate, external economic pressures – thus undermining them temporarily – but they may play a crucial role in view of long-term environmental and economic crises. Enhancement of buffer capacity and self-organization in alternative and locally rooted food systems may thus help to decrease the vulnerability of underdeveloped value chains.

At the same time, we found similar income levels in the agroindustrial and the agroecological food system in Bolivia, as well as in the agroindustrial and the local food system in Kenya. This finding is in line with the resilience study by Heckelman et al. (2018) and indicates that alternative and local food systems are not necessarily less viable economically, also given that their customer markets are strongly developing in Bolivia as well as in Kenya (Willer and Lernoud, 2017). At the time of our research, the Agroecological Platform in and around the city

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of Santa Cruz had around 30 active organizational and individual members. In Kenya, 30% of the households we interviewed in the local food system belonged to the Kenya Organic Agriculture Network (KOAN). In 2015, Kenya was among the 10 countries with the highest increase in land under organic cultivation (ibid.).

The agroecological food system displayed a higher overall resilience score than the agroindustrial food system in Bolivia, but certain weaknesses precluded it from being scaled up. It exhibited poor self-organization on the part of interest groups regarding different topics and levels, and, moreover, its value chains were rather poorly developed (see 3.5). In Kenya, the local food system displayed very low scores for resilience indicators such as human capital, learning, and feedback mechanisms (including social security and other support mechanisms). This casts doubt on narratives of functioning coexistence between smallholder farmers and agroindustrial food systems (see Altieri, 2005). In Bolivia, high livelihood assets indicate that actors of the agroecological food system were likely not among the poorest in the food value chain. Further, actors of the agroecological food system possessed a strong vision and the ability to try out new techniques and strategies. Finally, dependence on external factors in terms of inputs and markets remained high, and corresponding value chains remained poorly developed.

In summary, the ecological and economic potential of agroecological and local food systems may be high, but there is a prevailing lack of supportive infrastructure and functioning feedback mechanisms to help scale them up (see Esnouf et al., 2013). According to Blesh and Wittman (2015), the resilience of different food systems is closely linked to support at different government levels, and, more generally, to the political subsystem they are embedded within. Milestad and Darnhofer (2003) discussed the influence of regulations, subsidies, and global markets on the resilience of the organic farming movement, which can be regarded as another differentiated-quality food system. They conclude that the resilience and adaptive capacity of the organic movement has been diminished by current policy approaches. Rotz and Fraser (2015) argue that one key vulnerability of agroindustrial food systems is their reliance on engineering, infrastructure, and policy stabilizers. Removing any of these stabilizers could produce devastating results – an argument that is often used to keep them in place (see IPES-Food, 2016). Such mechanisms are also in place in the soybean sector in Bolivia, as evidenced by diesel subsidies (Urioste, 2012) and lack of enforcement of environmental laws/regulations on herbicides and seeds (Gonzales Soto, 2016). According to Rotz and Fraser (2015), such mechanisms have created food system incentives that sacrifice long-term resilience in favor of short-term productivity gains.

5 Conclusion

The present study sought to evaluate three dimensions of resilience in four different food systems in Kenya and Bolivia. It further aimed to identify differences and similarities that may be decreasing or increasing food system resilience, as well as leverage points for increasing food system resilience. Using indicators from resilience literature, we identified the following trends: (1) dominance of export-oriented agroindustrial food systems in both Kenya and Bolivia, as well as growing links between parts of agroindustrial value chains and other food systems (e.g., via rising use of agroindustrial inputs and supply of crops to agroindustrial processing, retail, and consumption facilities); (2) a corresponding high level of organization in interest groups and learning oriented on agroindustrial production; (3) lack of opportunities for local, and alternative food systems to strengthen and scale up, especially due to weaknesses in resilience factors like access to land, water, seeds, and machinery; lack of functioning feedback mechanisms; and poor self-organization. Relatedly, proper enforcement of existing laws could help to significantly

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improve the resilience of food systems, particularly regarding environmental aspects of buffer capacity, and self-organization. Finally, while the agroindustrial food systems featured high resilience scores regarding self-organization and capacity for learning and adaptation, they exhibited high inequalities and low ecological buffer capacity and self-regulation.

Complex and interlinked phenomena such as the trends we identified have often been analyzed independently from each other. Our resilience analysis helped to integrate social and environmental food system aspects, bringing together those factors – here treated as indicators – that build buffer capacity and self-organization as well as enable learning and adaptation. From our perspective, it is important to analyze resilience specifically as a system property and a pillar of sustainability. The latter, normative component of resilience is important because an apparently resilient food system may not be sustainable or desirable. Our assessment indicates that operationalization of resilience thinking regarding food systems may help to go beyond oversimplified approaches – e.g., "productionist" – that are inadequate in the face of our current multidimensional food system crisis. A comprehensive analysis of resilience enabled us to integrate dynamic aspects of food systems such as participation and learning, in addition to typical key concerns like availability or stability of food supplies. Future studies could focus on key aspects of resilience more than our broad study was able to do, for example on the diversity of food system components along value chains, e.g. assessing agrobiodiversity on farms, product diversity on markets, and dietary diversity on consumers' plates. Resilience analyses linked to sustainable development research can highlight ways in which insights from one food system can inform other food systems. This may be a more constructive pathway to solutions than focusing on how individual food systems can be made more resilient in isolation or how food security as such can be increased. There is an apparent need to identify resilience features that need to be transformed or enhanced in support of equitable food systems that are ecologically sustainable. Similarly, Folke et al. (2010) have emphasized the need to foster the resilience of smaller, more manageable social-ecological systems that contribute to the overall resilience of human life on the planet, and to *transform* social-ecological systems that currently decrease overall resilience.

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