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A social-ecological systems framework for food systems research: accommodating transformation systems and their products

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Abstract: The social-ecological systems (SES) framework was developed to support communication across the multiple disciplines concerned with sustainable provision and/or appropriation of common-pool resources (CPRs). Transformation activities (e.g. processing, distribution, retailing) in which value is added to resource units appropriated from CPRs were assumed in developing the framework to be exogenous to the SES of focal concern. However, provision and appropriation of CPRs are nowadays often closely integrated with the market economy, so significant interdependence exists between many CPR provision/appropriation activities and the activities in which appropriated resource units are transformed into the products ultimately marketed or consumed. This paper presents a modified version of the SES framework designed to better account for transformation activities in order to be more suitable for diagnosing those sustainability problems where it is inappropriate to define all such activities as exogenous to the SES of focal concern. The need for such modification was identified in a research project examining the challenges faced by Cambodian cattle-owning smallholders in accessing value chains for premium-priced beef. Hence the immediate focus was on strengthening the SES framework's value for facilitating a multi-disciplinary diagnostic approach to food system research projects of this kind. The modified SES framework's potential in this respect was illustrated by a preliminary application that drew on literature reviewed for the Cambodian project. Significant further potential exists in using the modified framework as a foundation from which to develop a version that is suitable for application to SESs in which transformation systems are appropriately represented as endogenous. Maintaining consistency with the standard SES framework will enable communication to occur more effectively between food system researchers and CPR scholars more generally.

Keywords: Common pool resources, food systems, institutional diagnosis, livestock marketing, social-ecological systems, value chains

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1. Introduction

The social-ecological systems (SES) framework was developed to facilitate cross-disciplinary communication among scholars interested in diagnosis of the sustainability of SESs in which provision and/or appropriation of common-pool resources (CPRs) occurs (Ostrom 2007, 2009). Activities where value is added to resource units (e.g. fish) appropriated from CPRs (e.g. fisheries) through transformation processes (e.g. grading, storage, processing, wholesaling, distribution, retailing, etc.) were assumed implicitly to be exogenous to the SES of focal interest; i.e. not influenced by activities, including policy decisions, undertaken within this SES (McGinnis and Ostrom 2014).[1]

Provision and appropriation of CPRs are nowadays often closely integrated with the market economy, with industrialisation and globalisation having brought markets for food and other resource units within reach of most of the world's population (Borghesi and Vercelli 2003). Hence significant endogeneity now exists between many CPR provision and appropriation activities and the value-adding activities in which appropriated resource units are transformed into the products or services ultimately marketed and consumed. For instance, retail demand for resource units appropriated from a particular CPR may depend on their attributes, including size and quality, which may in turn be influenced by the CPR institutions chosen (e.g. seasonal closure of a fishery versus size limits on vessels as means of constraining appropriation effort). The value of the SES framework for researchers studying such settings can depend therefore on its capacity to account for transformation (e.g. retailing) activities as endogenous to the SES of focal concern.

The need for a diagnostic framework capable of accommodating transformation activities within types of SES known as food systems (see Section 3.2) was identified in the process of designing the multi-disciplinary research project 'Domestic and international market development for high-value cattle and

[1] As observed below, however, some applications of the framework (e.g. Basurto et al. 2013) encompass primary transformation activities (e.g. grading, packing or storing resource units) that are closely related to appropriation activities.

beef in south-east Cambodia'.[2] This project aimed to promote implementation of Cambodia's Strategic Planning Framework for Livestock: 2011–2020 (Kingdom of Cambodia 2011) by supporting 'development of a market chain[3] that encourages smallholders in South East Cambodia … to access the Ho Chi Minh City, Phnom Penh and Siem Reap markets'[4] (Patrick 2010, 6). The rationale for improving such access was to alleviate the poverty of smallholders by enabling them to increase their incomes by sharing in the benefits from the higher prices paid for premium-quality beef in these more affluent markets. This has been a common rationale in recent years for projects funded in agricultural areas of developing nations, as discussed in Section 2.

Sobal et al. (1998) observed that a number of frameworks for analysing food systems had been proposed but that most focused on one disciplinary perspective or one segment of the whole system. It was judged when developing the Cambodian project that the SES framework was well-placed to fill this gap, particularly in respect of multidisciplinary diagnosis of food system performance, if it were possible when applying this framework to account for transformation activities within these systems as endogenous to the focal SES. With food systems a type of SES, considerable value was seen in extending the SES framework for application to instances of such systems that encompass transformation activities in addition to the natural resource provision and appropriation processes upon which those activities depend. The current version of the SES framework was designed to account for resource provision and appropriation activities but not for transformation activities, and thus has deficiencies as an instrument for diagnosing and understanding those food systems within which transformation activities play prominent roles.

The SES framework's focus on diagnosing the sustainability of natural resource provision and appropriation processes remains relevant for projects of this kind which aim to promote adoption by smallholders and other value-chain actors (e.g. slaughterhouse operators) of technologies and practices which may impact on natural resources (e.g. slaughterhouses require water supplies for their operation and may dispose of wastes to land and/or water systems). This relevance is highlighted by researchers (e.g. Godfray et al. 2010; Hanjra and Qureshi 2010; Tilman and Clark 2014) acknowledging the complexities in designing interventions to alleviate poverty and promote food security while sustaining CPRs and environmental systems more generally. The World Bank Group (2013) observed accordingly how expansion of farming frontiers into forested lands is greatly increasing the challenges of reducing greenhouse gas emissions through land-use changes.

[2] Australian Centre for International Agricultural Research (ACIAR) Project No. AH/2010/046.

[3] The term 'market chain' was used in this project interchangeably with 'value chain'.

[4] Ho Chi Minh City is the largest city in Vietnam, Phnom Penh is Cambodia's capital, and Siem Reap is a major international tourist destination in Cambodia.

The project's recognition of the value of the SES framework in diagnosing the complex challenges faced by smallholders in benefiting from the higher prices available in premium markets accords also with researchers (e.g. Ericksen 2008a,b; Donovan and Poole 2014) highlighting the escalating risks from relying on panaceas (e.g. trade liberalisation, farmer group marketing, etc.) in grappling with these challenges. Noting that 'economists in particular expect much of global food trade as a [food security] solution', for instance, Wahlqvist et al. (2012, 658) called for 'more nuanced and detailed forms of analysis of particular situations'.

A key aim of the Cambodian project was to develop a framework capable of helping researchers to perform such nuanced, detailed analyses in this domain. The project activity involving the present author aimed more specifically to 'develop an appropriate framework for diagnosing the performance of particular cattle market chains' which is 'sufficiently generic to be transferable to future research concerned with livestock market chains in other rural development settings' (Patrick 2010, 17). The modified version of the SES framework that was developed in the project for application to livestock-based food systems, and potentially to food systems more generally, is presented in this paper.

The Cambodian case is employed in this paper to highlight the value of modifying the SES framework to accommodate transformation activities and thereby a more comprehensive array of SESs within which occurs provision and appropriation of CPRs and environmental systems more generally. It is used in an illustrative exercise to highlight how the proposed modifications to the framework – to include 'transformation systems' and their 'products' as potential first-tier attributes of a focal SES in addition to the four represented in the existing SES framework as presented by McGinnis and Ostrom (2014) (i.e. 'resource systems', 'resource units', 'governance systems' and 'actors') – can broaden the search for factors potentially affecting SES performance, and thereby strengthen diagnosis of reasons for underperformance (although undertaking such a diagnosis is beyond the scope of this paper).

The challenges of rural development addressed by this project are similar to those experienced in other developing nations. An overview of the context of this project and how it relates to international efforts to alleviate poverty is presented in Section 2. Section 3 discusses two related concepts – value chains and food systems – that are central to the modifications to the SES framework made in the project to accommodate transformation processes involved in supplying consumers with beef and food products more generally. Key features of the SES framework relevant to effecting this accommodation are discussed in Section 4. Details of how the SES framework was modified to account for food system transformation activities are provided in Section 5. The contribution of the modified framework to strengthening multi-disciplinary diagnosis of sustainability problems, by providing a platform for a more inclusive exploration of variables that may be contributing to these problems, is illustrated in Section 6 by drawing from literature reviewed for the project. Finally, concluding comments are presented in Section 7.

2. The project in global context

More than 85% of the smallholders in south east Cambodia own cattle, and these cattle have traditionally been used as a source of draught power rather than as a source of income (Patrick 2010). There are very few specialist cattle producers. The vast majority of cattle is raised in smallholder production systems which typically involve subsistence agriculture together with cash-generating agricultural activities and off-farm activities. The raising of cattle relies significantly on feed available for scavenging within communally-managed lands (Harding et al. 2007).

It has been estimated that the demand for beef will increase by 22% in Cambodia, and double in neighbouring Vietnam, by 2020 (Patrick 2010). The project was motivated by the opportunities for smallholders to benefit in particular from participating in the growing markets for high quality beef in two Cambodian cities (Phnom Penh and Siem Reap) and Vietnam's Ho Chi Minh City. It focused on alleviating a number of obstacles to exploiting these opportunities, including: (i) cattle in south east Cambodia are challenged chronically by nutritional shortfalls and endemic diseases which impedes their suitability for quality beef markets; (ii) smallholders lack access to market information; and (ii) heavy reliance of smallholders on communal grazing and cutting of forage at distant locations during times of feed shortage (Patrick 2010). Lack of investment in the processing and marketing segments of livestock value chains has further limited the ability of Cambodian smallholders to access growing markets for high-value beef (Potter et al. 2007). The project sought accordingly to identify improved production and biosecurity practices and market structures that would strengthen the practical opportunities for south east Cambodian smallholders to access higher-value markets for their cattle and improve their livelihoods (Patrick 2010).

This project is one of many globally working towards a similar end in respect of the agricultural sector more generally. The *Millennium Goals Development Report 2013* found that 1.2 billion people in developing nations were living in extreme poverty (United Nations 2013). Much of the response to this crisis has focused on the agricultural sector and rural areas where poverty tends to be concentrated. Three-quarters of poor people in developing countries live in rural areas and most in these areas depend directly or indirectly on agriculture for their livelihoods (World Bank Group 2013). The World Bank (2007, 26) concluded accordingly that 'a more dynamic and inclusive agriculture could dramatically reduce rural poverty …'. With 2.5 billion rural inhabitants in these countries living in households involved in agriculture, and 1.5 billion of these in smallholder households, the World Bank (2007, 10) found further that 'improving the productivity, profitability, and sustainability of smallholder farming is the main pathway out of poverty in using agriculture for development'.

This pathway includes efforts to enhance participation by smallholders in high-value food markets. Demand for high-value food products in developing countries is growing rapidly due to rising incomes, increasing participation by women in the labour force, growing concerns for food safety and quality,

faster urbanisation, wider penetration of mass media, liberalised trade, foreign investment and technological advances (World Bank 2007). Increasingly, meanwhile, domestic food markets within developing countries are becoming integrated into global supply chains. These developments, along with evidence that participation in high-value food chains can increase farmer income by 10–100% (Flores et al. 2006), spurred interest in supporting smallholders to capitalise on the opportunities presented by the rise of such chains (London and Anupindi 2012).

Proponents of enhancing smallholder participation in high-value food chains recognise the obstacles. The World Bank (2007, 118) observed that 'modern procurement systems for integrated supply chains and supermarkets with stringent food-safety standards raise concerns about how to ensure that developing countries in general, and small farmers in particular, share in these growth opportunities [from growing demands for high-value agricultural products]'. A growing literature elaborates these obstacles (e.g. Hammond and Dube 2012; Lee et al. 2012; London and Anupindi 2012; Reardon et al. 2012).

Such proponents argue nevertheless that these obstacles can potentially be surmounted and that attempts to do so are justified because 'the payoff from assisting farmers to make the necessary 'threshold investments' can be high' (World Bank 2007, 127). The World Bank (2007) argued for public action to establish an enabling policy environment for smallholder participation in these food chains, including by regulating against opportunistic and uncompetitive behaviour in the marketing system. It also envisaged key roles for the private sector in enabling smallholders to participate as partners in modern procurement systems and exports, including by: establishing innovative vertical coordination arrangements with smallholders; facilitating access to credit, inputs, extension and certification; and supporting training of smallholders in the practices needed to satisfy food quality and safety standards. Public-private partnerships were seen as important for conducting the capacity building needed to develop and gain adoption of such practices. Other contributions to the literature on smallholder participation in high-value food chains include Marshall et al. (2006), Devaux et al. (2009), Patrick et al. (2010), Perez-Aleman (2012) and Donovan and Poole (2014).

We turn now to two important concepts for understanding the dynamics of connecting smallholders with expanding markets for premium-quality food products, and consequently for representing such challenges in the SES framework.

3. Value chains and foods systems: key related concepts for accommodating transformation activities in the SES framework

3.1. Value chains

Research and policy efforts concerned with enhancing smallholders' participation in high-value food chains have often incorporated the concepts and logic of global value chain (GVC) analysis as a focal approach in this endeavour. A value chain encompasses 'the full range of activities and services required to bring a product or

services from its conception to its end use' (London and Anupindi 2012, 12,338). Such a chain can be confined locally within a single enterprise or spread widely across space and multiple enterprises.

Particularly relevant to the research underpinning this paper, Lee et al. (2012, 12,326) discussed how the GVC approach can be used to 'specif[y] the role and position of smallholders within the interaction of global and local food value chains by mapping the geographic dispersion and organizational integration of these chains. It also highlights the governance structure of the chains by identifying lead firms that exert power to set the conditions for the inclusion of smallholders and the gains that accrue to them. This approach allows us to identify leverage points in food chains (i.e. those chain actors who can bring about desirable or deleterious changes for smallholders)'. London and Anupindi (2012) provided an example of the approach's value in this domain by applying it to identify the strengths and weaknesses of donor-led, enterprise-led and donor-enterprise-partnership initiatives in 'upgrading' smallholders to high-value food chains.

3.2. Food systems

A significant development in understanding challenges in pursuing food security is the increasing attention paid to the concept of food systems in the international research community focused on global environmental change (GEC). Food systems encompass food value chains in so far as they include 'a chain of activities from production ('the field') to consumption ('the table'), with particular emphasis on processing and marketing and the multiple transformations of food that these entail' (Ericksen 2008a, 235).

Proponents of this concept argue that comprehensive analysis of how such chains affect food security requires a food system to be defined more broadly than as a chain of activities. Hammond and Dube (2012) highlighted how food systems are affected by broader-scale biophysical factors (e.g. changes in climate patterns, environmental conditions) and sociopolitical factors (e.g. economic development, urbanisation, social norms) and the complex interactions between these. With about 40% of the world's land area occupied by agriculture (Alston and Pardey 2014), others including Godfray et al. (2010) have emphasised the importance of meeting growing demands for food in ways that are environmentally and socially sustainable. Ericksen (2008a, 234) defined a food system as the: (i) interactions between and within biophysical and human environments, which determine a set of activities; (ii) activities themselves (from production through to consumption); (iii) outcomes of the activities (contributions to food security, environmental security, and social welfare); and (iv) other determinants of food security.

A significant contribution of the food system concept to understanding smallholder participation in high-value food chains derives from its origins in the complex systems methodology typically followed in the GEC research community. From this perspective the social and natural dynamics of a particular food system are those of an SES – a type of complex adaptive system the emergent behaviour of

which can arise at multiple levels of various system scales (e.g. spatial, temporal, jurisdictional) as a consequence of numerous interacting influences. Social and natural conditions co-evolve such that changes in one trigger adaptations in the other. Surprises in the behaviour of SES are therefore to be expected, making capacity building for adaptation and transformation important for managing system vulnerability, resilience and robustness (Ericksen 2008a,b).

Research on food systems is challenging because 'solutions to managing environmental change and ensuring food security require a new integrated, multi-disciplinary research agenda' (Ericksen et al. 2009, 375). The challenge is amplified because each of the research disciplines involved has its own terminology, techniques and forms of data (Hammond and Dube 2012).

3.3. A role for the SES framework

As observed above, the SES framework is well-placed to address this challenge provided that modifications are made so that transformation elements of the food system can be accounted for as part of the focal SES. It is consistent with the food systems framework proposed by Ericksen (2008a,b) for structuring integration of research efforts in this area. Similar to the SES framework, this framework was intended to be 'fully inter-disciplinary, aiming for marriage of natural and social science …' (ibid., 237). It comprises four sets of food-system activities (producing food, processing food, packaging and distributing food, and retailing and consuming food) as well as three sets of outcomes from these activities (food security outcomes, social welfare outcomes, and environmental outcomes).

The elements of the food systems framework refer to a similar degree of abstractness as the first-tier attributes of the SES framework (discussed in the next section). One aim in developing the SES framework was to help accumulate a shared knowledge base across disciplines of how combinations of particular social and biophysical variables jointly affect outcomes in complex settings, with this shared knowledge serving to underpin a diagnostic approach to institutional design that is capable of addressing the 'panacea problem' which 'occurs whenever a single presumed solution is applied to a wide range of problems' (Ostrom and Cox 2010, 2). This approach seeks to identify 'what makes each resource use problem unique and what makes each case generalizable and comparable across settings' (Basurto et al. 2013, 1367). The inclusion (as described in the next section) of increasingly specific or 'concrete' attributes in the second, third and yet deeper tiers of the SES framework makes it more suited to a nuanced diagnostic role than the food systems framework. This is not to deny the considerable value of the food systems framework for other purposes.

A further reason to build on the SES framework is that it has already been widely applied, critiqued and refined (e.g. Fleischman et al. 2010; Ostrom and Cox 2010; Basurto and Nenadovic 2012; Schlüter and Madrigal 2012; Epstein et al. 2013; Garrick et al. 2013; Basurto et al. 2013; McGinnis and Ostrom 2014;

Nagendra and Ostrom 2014; Partelow 2015). It is significant also that the SES framework was developed from the Institutional Analysis and Development (IAD) framework which itself has been widely applied and extensively elaborated (Marshall 2005; Ostrom 2005), including by researchers focused on value chains for food (e.g. Devaux et al. 2009; Meinzen-Dick et al. 2009; Horton et al. 2011) and other primary products (e.g. Blam et al. 2000; Flinkman 2004), since it was developed over three decades ago.

Details of the existing version of the SES framework are presented in the following section prior to discussing in Section 5 why and how the SES framework was modified to better accommodate food systems (and other SES where it is inappropriate to define all transformation activities as exogenous to the SES of focal interest).

4. The SES framework

4.1. Overview

Ostrom (2009, 419) explained the structure of the SES framework as follows: 'SESs are composed of multiple subsystems and internal variables within these subsystems at multiple levels … In a complex SES, subsystems such as a resource system (e.g. a coastal fishery), resource units (lobsters), users[5] (fishers), and governance systems (organizations and rules that govern fishing on that coast) are relatively separable but interact to produce outcomes at the SES level, which in turn feed back to affect these subsystems and their components, as well as larger or smaller SESs'. The framework is multi-tiered, with each of the four subsystems (or first-tier attributes) distinguished in the preceding sentence unpacking to reveal a number of second-tier attributes which could each unpack into third-tier attributes, and so on.[6]

The SES framework distinguishes the SES of focal interest from its external environment which includes other SESs and is characterised by the two first-tier attributes *social, economic and political settings* and *related ecosystems.*[7] Defining the focal SES thus requires assessment of which attributes of the case under investigation can reasonably be deemed exogenous, given the temporal and spatial horizons of a particular research project, and to account for these under the attributes defined for the focal SES's external environment.

Central to the SES framework is the concept of *action situation* transferred from the IAD framework. This is where individual actors interact with one

[5] The updated version of the SES framework presented in McGinnis and Ostrom (2014) substitutes 'actors' for 'users' as the descriptor for the third subsystem in recognising that actors other than resource users can influence the condition of *resource systems*.

[6] Many of the second-tier attributes of the SES framework have been carried over into the SES framework modified for food systems research that is discussed below. Hence Table 1 below indicates the kinds of second-tier attributes included in the SES framework.

[7] References to attributes defined in the SES framework will hereafter be italicised.

another and thereby jointly affect outcomes (McGinnis and Ostrom 2014). These interactions and their outcomes affect and are affected by the attributes of the focal SES and its external environment (Ostrom 2010).

It is important to recognise that the SES framework is distinct from any theories or models that have been, or might be, proposed in respect of how various elements of the framework interact to generate particular outcomes. The framework is intended to provided a theory-neutral or 'metatheoretical' language to enable competing theories or models to be evaluated on a common basis (McGinnis and Ostrom 2014, 1).

4.2. Scope of *resource system* and *resource units*

The intention was clear originally that *resource system* and *resource units* referred to predominantly natural subsystems (e.g. fisheries) of SES and the units comprising or generated by them (e.g. fish), rather than to human-constructed biophysical subsystems [other than those accounted for by the second-tier attribute *human-constructed facilities* to capture those human-made biophysical supplements (e.g. irrigation infrastructure) to natural systems (e.g. rivers)] (Ostrom 2007, 2009). Less consistent with this original intention was the following openness of McGinnis and Ostrom (2014) to interpreting *resource system* more broadly:

> We are convinced that the SES framework may potentially be applicable to questions of the governance of an artificially constructed technological system such as a power grid or telecommunications system. … There is an important distinction between the relatively natural dynamics found in ecological systems and the constructed dynamic process of complex technical systems, but the distinction between natural ecology and artificial technology is not as clearcut as it may initially appear. After all, it is virtually impossible to find any ecological system in the contemporary era that is entirely free from human interference, nor are we aware of any [socio-ecological-technical] system in which the continued operation of the relevant technology bears no dependence on naturally occurring phenomena (2014, 7–8).

Consistent with this reasoning, Hinkel et al. (2015) presented a preliminary application of the SES framework to socio-technical systems of Austrian energy regions, where the technical subsystem of any such system was classified in the application as a *resource system*. McGinnis and Ostrom (2012) also raised the possibility of moving in this direction by changing the name of the *resource units* first-tier attribute to the more inclusive one of 'goods and services' that 'can be produced from inputs drawn from a Resource System', adding the caveat that this 'would move the resulting framework a long ways from its origins in questions of resource use, and would require a more explicit consideration of production, exchange, and other core concerns of the discipline of economics' (ibid., 15).

4.3. Reasons to distinguish natural and human-made biophysical systems as first-tier attributes

The reasons for developing the SES framework as distinct from the IAD framework are pertinent in considering refinements to the former to make it relevant for research into food systems. McGinnis and Ostrom (2014, 3) observed that, 'when applied to resource management issues, the natural tendency within the IAD framework is to treat the dynamics of a resource system as a mostly exogenous force, that is, as a driver of changing circumstances and not something directly under the control of the actors making policy in those settings'. With this tendency leading to increasing calls for a more ecologically sophisticated approach to researching SESs (e.g. Young 2002), the SES framework was developed recognising the importance of giving equal attention to both sides of human-nature interactions (Ostrom and Cox 2010). This recognition was demonstrated by including *resource system* and *resource units* in the framework as two of the four first-tier attributes of a focal SES.

Despite these moves in developing the SES framework to give greater attention to nature's side of human-nature interactions than had been the case with the IAD framework, the SES framework has been critiqued as lacking the level of attention to ecological attributes and processes that is needed to motivate natural scientists to participate in multi-disciplinary applications of this framework (Epstein et al. 2013; Vogt et al. 2015). Given this critique, it seems prudent if the scope of the framework were broadened to encompass transformation activities within the focal SES – and thus also predominantly human-made biophysical systems [i.e. 'technical systems' as referred to by McGinnis and Ostrom (2014)] – that natural systems be retained in the framework as a first-tier attribute rather than (a) conflated with human-made biophysical systems under a broadened definition of *resource systems*, or (b) demoted to a second-tier attribute of a new first-tier attribute referring generically to biophysical systems. While McGinnis and Ostrom (2014) observed aptly that the distinction between natural and human-made biophysical systems is not always clear-cut, the distinction is normally clear enough, at least between those that are predominantly natural vis-a-vis human-made, to invoke the principle of relative separability (used to distinguish the first-tier attributes of the existing SES framework) in designating natural and human-made biophysical systems as distinct first-tier attributes of a revised SES framework.

Allowing for this distinction in a revised framework would enable the lower-tier attributes of natural systems to be defined separately from those of human-made biophysical systems, and thus provide greater capacity to define attributes for each of these kinds of systems in accordance with input from leading scientists working on each of these distinct kinds of biophysical systems. For instance, Vogt et al. (2015) proposed that new second and third tier attributes of *resource systems* and *resource units* be included to incorporate ecological principles in the SES framework. Many of these new attributes (e.g. 'nutrient source-sink dynamics'

or 'multilevel trophic interactions/ cascades') are specific to natural systems and seem irrelevant as attributes of human-made biophysical systems.

Providing for a distinction in the framework between natural and human-made biophysical systems would also be more effective in prompting applications of the SES framework beyond SESs encompassing only biophysical systems that are predominantly natural, and thereby engage more productively with a broader range of food system issues. The challenge of accommodating predominantly-human-made biophysical systems within the SES framework has not arisen in its applications to date since their scope has been limited to SESs for which such systems were regarded as exogenous. This follows from the focus of the research tradition from which the SES framework emerged, and has so far been largely applied, having been on collective-action problems in the provision and appropriation of common-pool natural resources (Basurto et al. 2013). This research tradition led to identification of *human-constructed facilities* as a second-tier attribute of *resource systems* due to such facilities (e.g. irrigation facilities) sometimes having important roles in the provision or appropriation of natural resources (e.g. water).

Although the focus in this research tradition has largely been on provision and appropriation of natural resources, this focus has been broadened in some applications to encompass primary transformation activities that are closely associated with appropriation activities. In their application of the SES framework to a small inshore fishery in the Gulf of California, Mexico, for instance, Basurto et al. (2013) identified the storage facilities of the local fishing co-operative as part of the relevant CPR system. This begs the question, however, of why the focal SES was defined to encompass only this transformation activity from the full set of transformation activities potentially influencing social or ecological outcomes in respect of this fishery, and also potentially under the influence of policy makers concerned with this SES. Given that the current version of the SES framework does not explicitly recognise transformation activities as potentially part of a focal SES, there is nothing in it to prompt researchers to consider which if any of such activities should be included within the focal SESs they define in the process of applying the SES framework – or to justify why they included none of these activities or only some. The modified SES framework presented below seeks to remedy this weakness.

5. Accommodating food systems in the SES framework

5.1. Revisions to first-tier attributes

If the SES framework is to apply to SESs generally, and if food systems are SESs as indicated previously, then there is a case for exploring how the framework might be generalised for application to food systems that encompass value-chain activities beyond primary transformation activities. Consistent with the original motivation for developing the framework and the arguments presented above, however, the position taken here is that any such generalisation of the framework should retain the *resource system* and *resource units* first-tier attributes as they

were originally conceived; i.e. concerned with the dynamics and outputs of predominantly natural biophysical systems.

Two additional first-tier attributes – *transformation systems* (TS) and *products* (P) – have therefore been added to the four presently included in the standard SES framework to distinguish systems within an SES. Whereas the dynamics of *resource systems* are predominantly driven by natural processes, notwithstanding increasing human intervention, those of *transformation systems* are predominantly human-driven. *Transformation systems* and *products* are of course endogenous to types of SES other than food systems. For instance, they are important elements of the kinds of socio-technical systems (power grids, telecommunication systems and energy regions) which, as discussed above, McGinnis and Ostrom (2014) and Hinkel et al. (2015) argued were appropriate subjects for SES framework application.

The first-tier attributes in respect of *governance systems* and *actors* are extended in scope under this proposal to encompass *governance systems* and *actors* relevant to *transformation systems* and *products*. *Resource units* (e.g. litres of water) are understood in this extended framework as entities that may be appropriated from *resource systems*, which may be combined in *transformation systems* with other inputs to generate *products* (carcases produced by slaughterhouses, beef retailed by supermarkets, etc.). *Products* may include by-products, wastes or pollutants (e.g. drainage from slaughterhouse facilities) that interactions within action situations cause to be deposited to one or more *resource systems* (e.g. streams) within the focal SES and/or to *related ecosystems* (e.g, downstream wetlands), with positive or negative impacts on the functioning of those systems.

Figure 1 illustrates the first-tier attributes of the modified SES framework (hereafter called the SES(T) framework to denote that its explicit accommodation of transformation systems distinguishes it from the current standard version of the SES framework) for diagnosing food-focused SES that arise from these modifications to the SES framework, as well as the relationships between these attributes. The attributes inside the dashed-line box are those of the focal food system, and those outside it refer to its external environment.

The four sets of value-chain activities (producing food, processing food, packaging and distributing food, and retailing and consuming food) included in the food systems framework can be accounted for in the modified SES framework as sets of *activities and processes* within *focal action situations*, and the three sets of outcomes included in the food systems framework (food security, social welfare and environmental outcomes) are accounted for in the modified SES framework by way of the *outcome criteria* component of *focal action situations*. Moreover, the modified SES framework can account for the diversity of factors and types of interactions affecting food security (and associated social and environmental outcomes) which the food systems framework primarily focuses on.

Consistent with previous applications of the SES framework in analysing provision and appropriation of natural resource systems, *resource units* include those transformed by relevant primary production processes (e.g. as filleted fish, trimmed logs, fattened livestock), and *resource systems* include such processes.

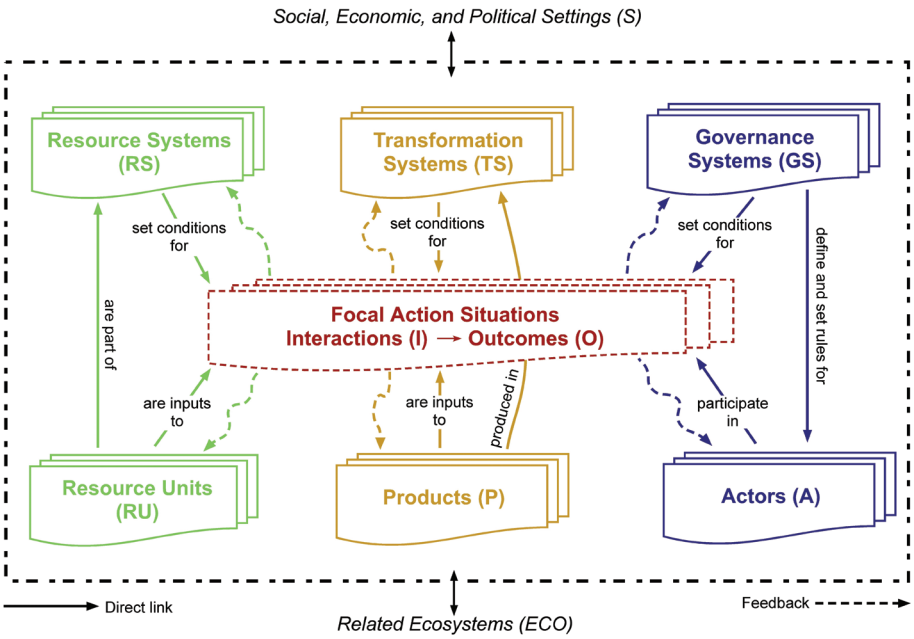

Figure 1: The SES(T) framework – the SES framework as modified for food systems research [adapted from McGinnis and Ostrom (2014, figure 2)].

Hence, *TS* refers to systems in which secondary (e.g. processing and packaging) and tertiary (e.g. distribution, hospitality, consumption) transformation processes occur, and *P* refers to the products generated by these processes.

Decisions about which, if any, *transformation systems* or *products* should be included as part of the focal SES (i.e. focal food system in the case of food systems research) depend on researcher judgement. A particular *transformation system* or *product* should be included within the focal SES, or focal food system, where a researcher judges it to be endogenous to the system; i.e. systematically influenced by other elements of the system. Conversely, a *transformation system* or *product* should be defined as part of the system's external environment (and more specifically as part of its *social, economic and political settings*) when a researcher identifies it as exogenous to the system; i.e. not systematically influenced by other system elements. In the case of subsistence food systems, for instance, it would be appropriate to include at most primary *transformation systems* (and *products* derived therefrom) as part of the focal SES or food system.

5.2. Revisions to second-tier attributes

Considerable work remains in following through the implications of this proposed extension of the scope of the SES framework for the attributes presently identified

at its second and deeper tiers. A need for some changes is nevertheless immediately evident. For instance, accommodating *transformation systems* within a focal SES means that the list of *activities and processes* identified as second-tier attributes of a *focal action situation* needs to be augmented to include *transformation activities*. (Appropriation and primary production activities are covered already by *harvesting activities*, and provision is covered by *investment activities*).

Accommodating *transformation systems* within a focal SES also raises a need to include *exchange activities* as a second-tier attribute of a focal action situation since *products* generated by such systems are commonly exchanged through markets, contractual arrangements and the like. Encompassing market exchange activities within the scope of a focal SES has further implications because the current version of the SES framework identifies *markets* as a second-tier attribute of the *social, economic and political settings* component of the external environment, reflecting an assumption that all market-related dynamics are exogenous to a focal SES. Hence, broadening the scope of a focal SES to encompass market exchanges of the products generated within it means that the relevant second-tier attribute of *social, economic and political settings* needs to be respecified as *other markets*.

The next step in revising the SES framework for application to food systems involved considering the more general implications for its second-tier attributes of adding *transformation systems* and *products* as first-tier attributes. The process of specifying second-tier attributes for the current SES framework benefited from considerable prior research into provision and appropriation of a wide variety of common-pool natural resources (e.g. forests, grasslands) in diverse natural and cultural settings that was informed by the logic of the IAD framework from which it was developed. Given the few studies of food value chains that have been informed explicitly by the IAD framework (Devaux et al. 2009; Meinzen-Dick et al. 2009; Horton et al. 2011), there is a limited knowledge base to readily draw from in specifying second-tier (and deeper) attributes of a revised SES framework applicable to all types of food value chains (e.g. vegetables, pigmeats) across all natural and cultural settings.

This step was limited accordingly to preliminary identification of the second-tier attributes of the SES(T) framework. The initial focus was on specifying second-tier attributes of the two newly-introduced first-tier attributes, although it was important to assess whether second-tier attributes elsewhere in the framework also needed to be revised or augmented to enhance its suitability for food systems analysis. The starting points in specifying second-tier attributes for the two new first-tier attributes – *transformation systems* and *products* – were the second-tier attributes for *resource systems* and *resource units*, respectively. These seemed relevant for the new first-tier attributes.

The adequacy of this augmented set of second-tier attributes was tested by reviewing two sets of literature to identify attributes that should be added, subtracted or redefined to make the SES framework more applicable to food systems. As mentioned previously, this process was undertaken as part of a

multi-disciplinary research project concerned with market development for cattle and beef in Cambodia. The first set of literature that was reviewed consisted of the few studies of value chains for food products that have applied or incorporated the IAD framework (Devaux et al. 2009; Meinzen-Dick et al. 2009; Horton et al. 2011). The other set comprised publications relevant to identifying key influences on the performance of:

- cattle value chains in Cambodia and its region (Harding et al. 2007; Hawkins et al. 2012; Kerr et al. 2012; Sieng et al. 2012; Hoang et al. 2013);
- livestock value chains in Cambodia (Potter et al. 2007; Kingdom of Cambodia 2011) and developing countries generally (Food and Agriculture Organization 2011); and
- non-livestock food and related value chains in developing countries generally (Gibbon 2001; Reardon and Berdegué 2002; Dolan and Humphrey 2004; Gibbon and Ponte 2005; Humphrey 2008; M4P 2008; Hellin et al. 2009; Kruijssen et al. 2009; Markelova et al. 2009; Okello et al. 2009; Ouma et al. 2010; De Asis 2011).

The outcome of this process was the list of second-tier attributes presented in Table 1. This process established that all the second-tier attributes of *resource systems* were relevant for *transformation systems*, and all the second-tier attributes for *resource units* were relevant for *products*. The names of the attributes were translated where necessary in accordance with the subsystem to which they apply (e.g. *size of resource system* was translated to *size of transformation system*, *resource unit mobility* to *product mobility*, etc.).

This process also led to a number of other minor modifications to the SES framework, detailed in the appendix, to make it more applicable to food systems.

6. Illustrating how the SES(T) framework strengthens the analytical basis for food system diagnosis

An illustrative application of the SES(T) framework that draws on literature reviewed for the research project 'Domestic and international market development for high-value cattle and beef in south-east Cambodia' is presented below. The focal food system (as the relevant SES) in this instance comprises the particular *resource systems*, *resource units*, *transformation systems*, *products*, *governance systems* and *actors* that interact in particular *focal action situations* to influence smallholder participation in value chains for high-priced beef (e.g. sourced from smallholder cattle owners in Pursat Province and retailed in Phnom Penh supermarkets). Note that parenthesised codes (e.g. R2) in the following discussion refer to the corresponding attribute in the SES(T) framework (Table 1).

The purpose of this illustrative exercise is to highlight how the SES(T) framework strengthens the capacity of the standard SES framework to facilitate

Table 1: First- and second- tier attributes of the SES(T) framework.

Social, economic, and political settings (S) S1- Economic development. S2 - Demographic, social and cultural settings. S3 - Political stability. S4 - Other governance systems. S5 - Other markets. S6 - Media organisations. S7 - Other technology and infrastructure. S8 - History		
Resource systems (R)	**Transformation systems (T)**	**Governance systems (GS)**
R1 Sector	T1 Sector	GS1 Policy area
R2 Clarity of system boundaries	T2 Clarity of system boundaries	GS2 Geographic scale of governance system
R3 Size of resource system	T3 Size of transformation system	GS3 Size of population involved or affected
R4 Human-constructed facilities	T4 Human-constructed facilities	GS4 Regime type
R5 Productivity of system	T5 Productivity of system	GS5 Rule-making organisations
R6 Equilibrium properties	T6 Equilibrium properties	GS6 Rules-in-use
R7 Predictability of system dynamics	T7 Predictability of system dynamics	GS7 Property-rights systems
R8 Storage characteristics	T8 Storage characteristics	GS8 Repertoire of norms and strategies
R9 Location	T9 Location	GS9 Network characteristics
R10 Inputs	T10 Inputs	GS10 History
Resource units (RU)	**Products (P)**	**Actors (A)**
RU1 Resource unit mobility	P1 Product mobility	A1 Number of actors
RU2 Growth or replacement rate	P2 Growth or replacement rate	A2 Socio-economic attributes
RU3 Interaction among resource units	P3 Interaction among products	A3 History or past experiences
RU4 Economic value	P4 Economic value	A4 Location
RU5 Number of units	P5 Number of units	A5 Leadership / entrepreneurship
RU6 Distinctive characteristics	P6 Distinctive characteristics	A6 Norms (trust-reciprocity) / social capital
RU7 Spatial and temporal distribution	P7 Spatial and temporal distribution	A7 Knowledge of SES / mental models
RU8 Marketing characteristics	P8 Marketing characteristics	A8 Importance of resource (dependence)
		A9 Technologies

Table 1: (continued)

Action Situations: Interactions (I) → Outcomes (O)	
Activities and Processes	**Outcome criteria**
I1 Harvesting	O1 Social performance measures
I2 Information sharing	O2 Ecological performance measures
I3 Deliberative processes	O3 Externalities to other SESs
I4 Conflicts	
I5 Investment activities	
I6 Lobbying activities	
I7 Self-organising activities	
I8 Networking activities	
I9 Monitoring and sanctioning activities	
I10 Evaluative activities	
I11 Transformation activities	
I12 Exchange activities	
Related Ecosystems (ECO)	
ECO1- Climate patterns; ECO2 - Pollution patterns; ECO3 - Flows into and out of focal SES	

Source: Adapted from McGinnis and Ostrom (2014, tables 1 and 2).

multi-disciplinary diagnosis of food system sustainability issues. The SES(T) framework strengthens this capacity in two ways. Firstly, it prompts researchers to consider attributes of various food system transformation systems and products, in addition to the attributes covered by the standard SES framework, in the process of considering what factors and relationships are most relevant to understanding a food system sustainability issue of focal concern (e.g. lack of smallholder adoption of biosecurity practices recommended for cattle, non-compliance of beef retailers with health regulations, etc.). Secondly, the framework prompts researchers to consider those attributes of the other subsystems represented in the framework (*resource systems; resource units; governance systems*; *actors; social, economic and political settings;* and *related ecosystems*), that may be significant for understanding how relevant *transformation systems* and *products* relate to the issue of focal concern. For instance, the socio-economic characteristics (e.g. ethnicity, religion, etc.) of beef retail proprietors (*actors*) may help to understand their meat purchasing decisions and thus their impacts on the prices received by smallholders (*outcome criteria*).

Let us turn to the first of these contributions and provide a few examples from the relevant literature of the kinds of attributes of *transformation systems* and *products* that inclusion of these subsystems in the SES(T) framework may lead researchers to identify as potentially significant for understanding participation of south-east Cambodian smallholders in markets for high-value beef. Food retailing is one relevant category of food transformation systems, which itself includes multiple subcategories (wet markets, supermarkets, etc.). Each of these subcategories (e.g. supermarkets) depends on a diverse array of inputs (e.g. carcases, packaging and labelling materials, electricity, water, etc.) (T10). Cambodian smallholders' ability to supply cattle to value chains for high-quality beef is limited by lack of infrastructure in downstream *transformation systems* including saleyards, weighing facilities, cold-chain facilities and good roads (Harding et al. 2007), while inadequate transport facilities cause injuries to cattle (Sieng et al. 2012) (T4) which can reduce their market value (RU4). Lack of cold-chain facilities (T4) limits the ability to store products along the value chain to manage supply surpluses (T8) (Potter et al. 2007).

A variety of *products* (P) (e.g. transported cattle, carcases, by-products, processed items, fresh beef) are generated from the relevant *transformation systems*. The ability to maintain the condition of cattle until slaughtering (P2, P8) is limited by poor infrastructure for handling and transporting cattle (T4), while the quality of carcases and fresh beef (P8) through post-slaughter steps of the value chain is limited by lack of cold-chain facilities (T4). Limited scope to store products due to lack of cold chain facilities constrains storage as a way of smoothing out price fluctuations arising from surpluses or deficits in their supply (P4). Hoang et al. (2013) found that beef consumers in Ho Chi Minh City were on average willing to pay 35% more for 'quality certified beef' than for non-certified beef, and that realising this premium would increase the value of cows exported from Cambodia to Vietnam (P4, GS6).

Now we turn to the second of the abovementioned contributions from accommodating *transformation systems* and *products* in the SES(T) diagnostic framework, and illustrate from the relevant literature how this accommodation serves to prompt researchers to consider attributes of the framework's other subsystems that may otherwise be overlooked when exploring the range of factors that might be influencing participation by south-east Cambodian smallholders in high-value beef markets.

Relevant to the *social, economic and political settings* (S) subsystem, for instance, Harding et al. (2007, vi) observed that 'the poor state of market, transport and communication infrastructure [S7], and the often counter-productive impact of government regulation [S4] work against the development of production and processing chains [T] for livestock that smallholders can easily fit into [O1]'. They reported also that rapidly increasing production of pigmeat and poultry in Cambodia's region (S5) was identified as potentially limiting future demand for its beef (P4) (ibid.).

Pertinent to the *resource systems* (R) subsystem, Potter et al. (2007) found that the overall scale of livestock production (R3) in an average Cambodian commune was sufficient to justify establishing at least one livestock marketing facility (T4) in each commune. Of relevance to the *resource units* (RU) subsystem, however, they found that the relatively low density of cattle production across the landscape (RU7) works against investing in local infrastructure like saleyards (T4) to facilitate their marketing. The mobility of cattle as products traded along the value chain (P1) means they can be walked short distances (e.g. off-road across the Cambodia-Vietnam border) but also increases the risks of disease transmission due to their ability to move amongst one another (e.g. within holding facilities) and interact with other livestock they pass (P3) (Hawkins et al. 2012). Diseased cattle may in turn lose condition (P2) and market value (Sieng et al. 2012) (P4).

In respect of the *actors* (A) subsystem, about three-quarters of the cattle traders interviewed by Sieng et al. (2012) raised livestock themselves (A2). Only 18% of their respondents desired to be involved in international trade, with the reasons for disinterest including lack of prior experience with that trade (A3). They found also that livestock trader networks operating across Cambodia are largely based on informal social capital (A6). Most of their interviewed traders realised that livestock diseases could be spread by transporting sick livestock (A7) but did not routinely follow biosecurity practices (e.g. truck washing) relevant to their activities (A9). Hoang et al. (2013) found that around 80% of beef consumers at supermarkets in Phnom Penh had completed at least high school education, compared with about 30% of beef consumers at traditional markets (A2).

The various *transformation systems* involved in the south-east Cambodian case are each subject to *rules-in use* (e.g. food safety regulations, environmental policies) (GS6) under various *governance systems* (GS). The cattle traders interviewed by Sieng et al. (2012) identified four government organisations, and one private trading company, from which approval can be required for them to operate (GS5). Potter et al. (2007) reported that most private actors in Cambodia's

livestock value chains regard efforts to enforce regulations as 'extractive' and thus follow a norm of avoiding payment of statutory fees wherever possible (GS8). They identified poor linkages between public and private organisations as a constraint on developing value chains for Cambodian cattle (GS9). Potter et al. (2007) noted that challenges arise in adapting value chains for Cambodian livestock to strengthening consumer demands for high-quality meat because existing governance arrangements evolved for 'scavenger' herds that grazed communal lands (GS10).

The foregoing brief application of the SES(T) framework to a specific challenge in food system performance (promoting smallholders' participation in premium markets for their produce) illustrates its capacity, compared with the standard version of the SES framework, to broaden the search for factors potentially affecting this performance and thereby enrich diagnosis of reasons for underperformance. Some of the reasons for underperformance may indeed reside in the subsystems covered in the standard version. The land resources available to smallholders, for instance, may not be suitable for delivering the quality or regularity of produce required for participation in premium value chains. It can normally be expected, however, that at least some of the key reasons will relate to attributes of *transformation systems* and *products* that are not represented in the standard version of the SES framework. Prospects for policy success in strengthening food system performance will be diminished to the extent that key reasons for underperformance remain undiagnosed.

Continuing development and validation of the SES(T) framework in respect of different kinds of food systems and contexts is required to fulfil its potential as a diagnostic instrument for research in this field, particularly because it has been applied to date only in the project from which it was developed. This application focused on identifying the attributes of value chains for cattle in south-east Cambodia on which data would be collected in a face-to-face survey of smallholders in this region. This survey sought to collect data relevant to understanding the ability of these smallholders to participate in value chains for premium beef (East et al. 2013). The first and second tier attributes of the SES(T) framework were used in a series of meetings with project team members across various disciplines to structure discussions on (i) what information was already available on these attributes regarding the action situation on which the survey was focused (i.e. smallholder participation in premium value chains for their cattle), and (ii) the most critical information gaps to fill through the survey. The framework was valuable in this process for facilitating discussions between project researchers from multiple disciplines (agricultural economics, livestock production, veterinary science, rural extension). It enabled them to recognise the contributions and limitations of their own disciplinary perspectives in designing a questionnaire matched to the broad focus of the survey on understanding smallholder participation in premium value chains, and acknowledge the need for the questionnaire design to be informed also by other disciplinary perspectives. The questionnaire that emerged from this process was considerably more inclusive

of the wide spectrum of relevant elements of the focal food system than would otherwise have been the case.

7. Closing comments

Food system issues involve complex interactions across multiple scales (e.g. social, ecological and institutional), so careful multi-disciplinary diagnosis of each such issue is vital for identifying responses well-matched to their unique attributes. The modified SES framework presented in this paper, called the SES(T) framework to recognise its accommodation of transformation activities in addition to the resource provision and appropriation activities which the current version of the SES framework focuses on, was developed as an instrument for researchers and policy analysts to employ in diagnoses of this kind.

Significant work remains in developing the SES(T) framework to make it a more practical instrument for structuring multi-disciplinary inquiries into food system issues in the context of environmental limits from local to planetary levels. It is important meanwhile that commons scholars concerned with food system issues apply the framework to their particular cases in order to identify any refinements or elaborations that are needed to broaden its applicability to food systems generally.

The goal is for the SES(T) framework to be developed to the stage where it serves as a common language for food system scholars to use routinely in structuring and reporting their investigations of all types of food systems across diverse settings. Moves in this direction will promote the comparability of research findings in this sphere needed for the kinds of meta-analyses on which knowledge accumulation depends. Maintaining consistency with the current standard SES framework enables the relevance to food systems of findings from research into other types of SES (e.g. research into determinants of collective action by villagers in managing common-pool natural resources) to be assessed more confidently, and vice versa.

Appendix

Minor modifications in adapting the second-tier attributes of the SES framework to food systems

Technologies available, a second-tier attribute of *actors*, was generalised to *technologies available/used*, recognising that use of technologies can influence actors' impacts within food systems.

Inputs was added as a second-tier attribute of both *resource systems* and *transformation systems* recognising that the particular inputs used within these systems (e.g., commercial fertilisers applied to *resource systems* used for livestock production) influence their dynamics. *Marketing characteristics* was added as a second-tier attribute of both *resource units* and *products* recognising that characteristics of this kind (e.g., bulkiness, perishability) can help understand

choices by value-chain actors concerning *exchange activities* for particular *resource units* (e.g., fattened cattle) and *products* (e.g., carcases).

The modifications to the second-tier attributes of *governance systems* suggested by McGinnis and Ostrom (2012) were incorporated when adapting the SES framework for application to food systems. Garrick, De Stefano et al. (2013) and Basurto, Gelcich et al. (2013) incorporated these suggestions in their applications of the framework. Some modifications to these suggestions were made when incorporating them within the F-SES framework. The suggested attribute *population* was renamed *population involved/affected. Network structure* was generalised to *network characteristics* to allow non-structural attributes of governance networks (e.g., power relations) to be accounted for. *Historical continuity* was generalised to *history* recognising that multiple aspects of the history of governance arrangements (e.g., history of governance performance) other than their degree of continuity can influence their dynamics and performance.

Monitoring activities, a second-tier attribute of the *activities and processes* component of *focal action situations*, was broadened to *monitoring and sanctioning activities* since sanctioning activities (formal and informal efforts to enforce rules) were not explicitly covered in the framework.

Demographic trends, a second-tier attribute of *social, economic and political settings*, was generalised to *demographic, social and cultural settings* to encompass a range of attributes of the socio-economic external environment of a food system (e.g., existing demographic patterns, class or ethnic composition of society) not covered by *demographic trends* nor any other existing second-tier attributes of this external environment. *Technology*, another second-tier attribute of *social, economic and political settings*, was changed to *other technology and infrastructure* to distinguish the exogenous technology referred to here from the endogenous technology included as a second-tier attribute of *actors* and the endogenous *human-constructed facilities* included as second-tier attributes of *resource systems* and *transformation systems*.

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