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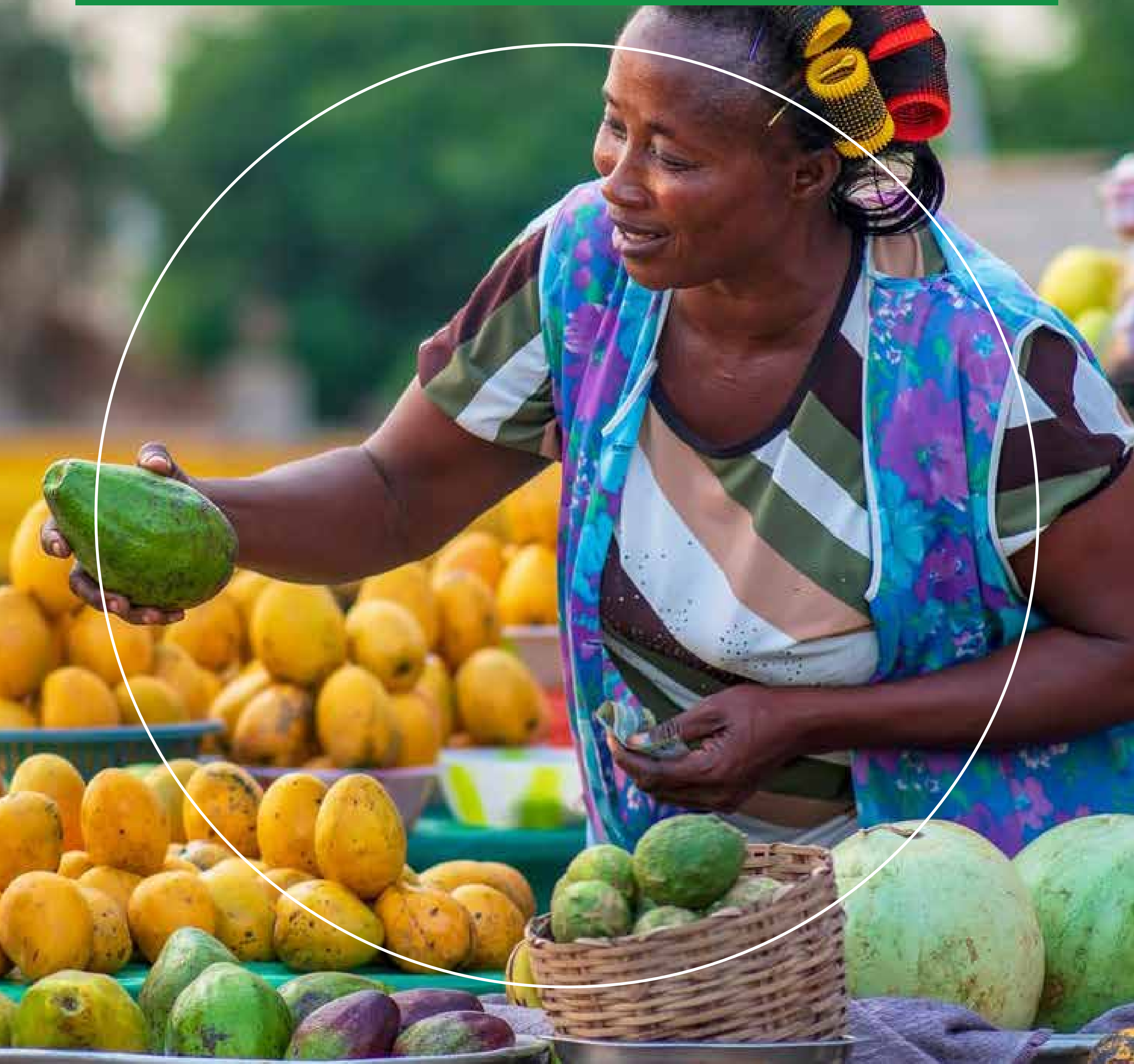

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This study was carried out by Wageningen Economic Research and was commissioned and financed by the Dutch Ministry of Agriculture, Nature and Food Quality within the context of the Food Security and Valuing Water research theme of the Policy Support/Knowledge Base/Statutory Research Tasks (project number BO- 5200047454.

Wageningen Economic Research
Wageningen, July 2022

POLICY PAPER
2022-082

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Hubert Fonteijn, George van Voorn, Geerten Hengeveld and Bart de Steenhuijsen Piters, 2022. *Assessing the impact of interventions on food systems resilience.* Wageningen, Wageningen Economic Research, Policy Paper 2022-082. 20 pp.; 3 fig.; 6 tab.; 17 ref.

The resilience of food systems is becoming increasingly important in securing consumer access to food, but also people's ability to generate income from agriculture and agri-businesses. Any assessment of interventions in a food system should include an assessment of the effects these interventions will have on the resilience of that particular system. However, measuring the effects of interventions on food systems resilience is not straightforward, as we cannot simply add up the different component parts of resilience (i.e., of what and who). Food systems contain many interdependencies between different stakeholders and their economic and ecological environments, and these result in trade-offs and synergies. Any policy intervention can be expected to not only affect the specific resilience target, but also other parts of the system – and this should be considered in any assessment. This paper offers a practical assessment framework to support policymakers and impact investors aspiring to strengthen food system resilience or predict the effects of their policies and investments on food system resilience.

Key words: food systems, resilience

This Policy Paper can be downloaded for free at https://doi.org/10.18174/574453 or at www.wur.eu/economic-research (under Wageningen Economic Research publications).

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Wageningen Economic Research Policy Paper 2022-082 | Project code 5200047454

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1 Introduction

The ability of food systems to withstand and recover from shocks – commonly referred to as 'resilience' - is becoming increasingly critical, as has been exemplified by the impacts of the COVID-19 pandemic (Béné 2020, Piters, Termeer et al. 2021). Although the pandemic has affected everyone's life, the impact on food security has been predominantly felt by the poor, especially in low- and middle-income countries (LMIC). These groups had already been suffering from unstable livelihoods and chronic food insecurity pre-crisis, which made them more vulnerable and less prepared to withstand further shocks and crises. The importance of building food systems that are resilient to both local and global events has become even more salient during the current war in Ukraine. Trade in grain, but also artificial fertilisers is severely hindered by the direct effects of the war and by trade blockades. The effects of this shock are expected to keep building as commodity and fertiliser stocks run out, which will cause food prices to be high for the foreseeable future. Again, this crisis will impact mostly the poor, first in Africa and the Middle East and then around the world as the effects of fertiliser shortages will start to affect local harvests.

The last century has seen substantial increases in agricultural production and yields (through the green revolution). Simultaneously, there has been an increase in the level of urbanisation and globalisation of trade. The increasingly internationalised food market has supported specialisation by promoting agricultural activities in the locations that are the most competitive globally, leading to a gain in ***efficiency***. However, these developments are not without risk, as food systems around the world are showing signs of being under pressure (e.g., by depletion of soil and inputs). Moreover, climate change is altering growing conditions around the world and is increasing the probability of extreme weather events, such as floods, droughts, and hurricanes (Stott, Christidis et al. 2016). When these are concurrent with other crises, such as the current war in Ukraine, the 2007-2008 food price crisis, or the COVID-19 pandemic, conditions may be created that lead to a considerable reduction in productivity or even the collapse of (local) food systems (Ehrlich and Ehrlich 2013).

The resilience of food systems has therefore become more and more a priority for policy makers. When evaluating interventions into a food system, policy makers should therefore be able to assess the effects of these interventions on that system's resilience. While it is clear ***why*** we want to assess food system resilience, ***how*** to do so is much more complicated. A food system is a **complex network** of activities relating to production, distribution, processing, and consumption that connect people to food. Such systems operate at multiple spatial and organisational scales, and span social, ecological and economic relationships (Schipanski, MacDonald et al. 2016). These complexities mean that measuring the impact of a policy intervention or investment on the food system (including resilience) is not straightforward and that predicting such impact is challenging, since interventions are likely to affect not only their specific targets, but also other food system properties. The complexity of the food system, moreover, results in **trade-offs** and synergies. An intervention or investment may enhance resilience for one part or segment of society of the food system, while simultaneously reducing the resilience of others. For example, higher productivity is often associated with specialisation in a single crop – which increases local susceptibility to disease and adverse weather and makes the farmer more dependent on the local market for other food items. Similarly, Just-In-Time delivery reduces storage costs within supply chains but removes all buffers to supply-chain breaches. In addition, across the food system, low food prices favor food accessibility for vulnerable urban populations but reduce revenue – and financial buffers – for farmers.

Finally, resilience itself is difficult to define and operationalise. Although it is attractive to consider resilience as a consolidated food system property, it is more appropriate to acknowledge that resilience should always be made specific to the system, scales, and objectives under consideration. This means that resilience should be defined as **resilience of what, to what** (Carpenter, Walker et al. 2001), and for whom (Cutter 2016). Conversely, this means that each property of the food system (of what), will have a resilience against any shock (to what) from the perspective of each participant (for whom). Resilience is thus distributed within the food system.

In summary, the evaluation of food systems resilience is challenging for researchers and policy makers because both food systems and resilience are complex and multifaceted concepts. **This paper aims to create a practical assessment framework that incorporates food system complexity and trade-offs to support policy makers and impact investors, who aspire to strengthen food system resilience or predict the effects of their policies and investments on food system resilience.**

To develop this framework, we first discuss the definitions of food systems, resilience, and resilience within food systems. We base this framework on the **ABCD** properties of resilience introduced in "Understanding Food System Resilience" (Piters, Termeer et al. 2021) and discuss their operationalisation within specific food system contexts. Finally, we provide guidance on how to: 1) identify and define the food system that is subject to intervention; 2) describe how resilience properties are distributed within the food system; and 3) assess what the potential impact of a specific intervention on this distribution of resilience is.

2 The **ABCD** of food system resilience

Understanding the impact of interventions on food systems resilience requires an understanding of food systems and of what resilience means in this context. A **food system** includes all processes, actors and activities associated with food production and food utilisation, from growing and harvesting to trading, processing, transporting and consuming (see Figure 1). It is important to realise that a food system is not a static entity, and that its boundaries are often not clearly delineated. Beyond supply, a food system also encompasses the wider food environment: socio-economic drivers such as policies, innovation, education and social norms, and environmental drivers including climate, soil and biodiversity.

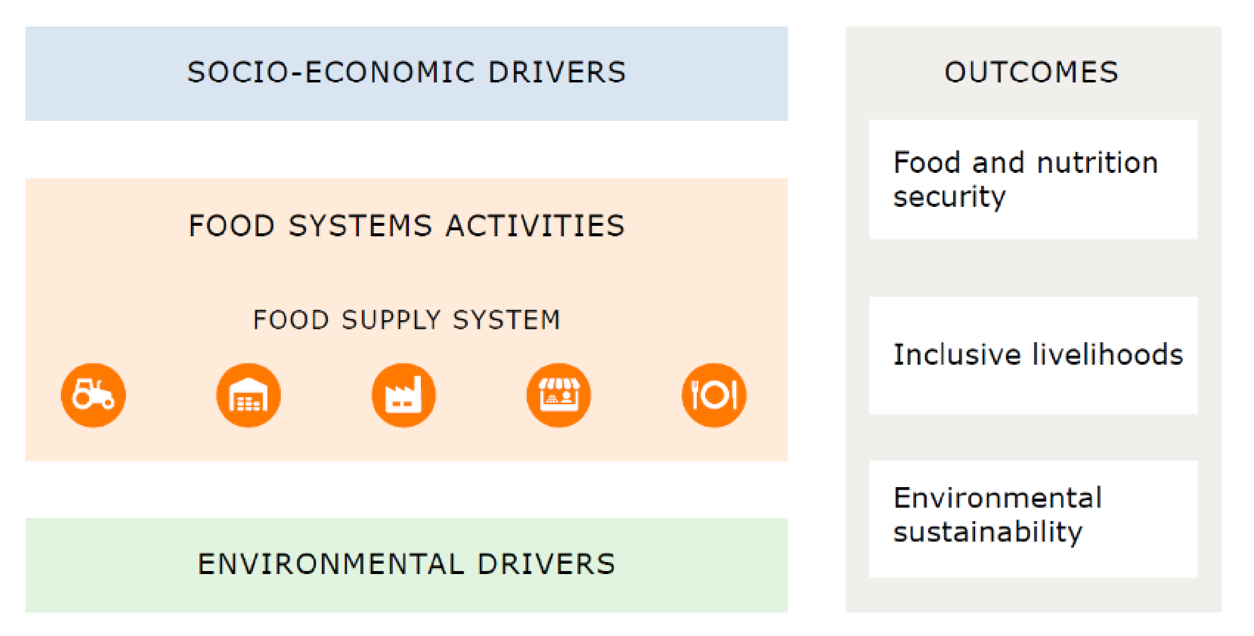

Figure 1 *Simplified visualisation of a food system*
Source: adapted from (Van Berkum, Dengerink et al. 2018)

A food system is hence more than the central supply chain and consists of multiple locations where shocks or interventions can affect the system. The way in which food system attributes protect against shocks and stressors varies from specific to the threat at hand – for example, a dam prevents floods from entering fields – to more general protection against many shock types (e.g. financial buffers). A previous analysis of the existing literature on resilient food systems (Steenhuijsen Piters, Termeer et al. 2021) identified various important properties to consider when looking at resilience, ranging from access to both distant and local food production, the diversity of local food production to the state of rural infrastructure and local self-organisation. From these, four summarising aspects were derived that define the response capacity, i.e., the resilience of food systems. While these four properties are by no means exhaustive, they do span a diverse set of factors that underpin resilient food systems. Previously, these properties were presented as the **ABCD** of resilience building (see Figure 2):

Agency: the means and capacities of people to mitigate risks and respond to shocks.
Buffering: resources to fall back on in the face of shocks and stressors.
Connectivity: the connections and communication between actors and market segments.
Diversity: diversity at different scales and in different places, from production to consumption and from farm level to regional diversity.

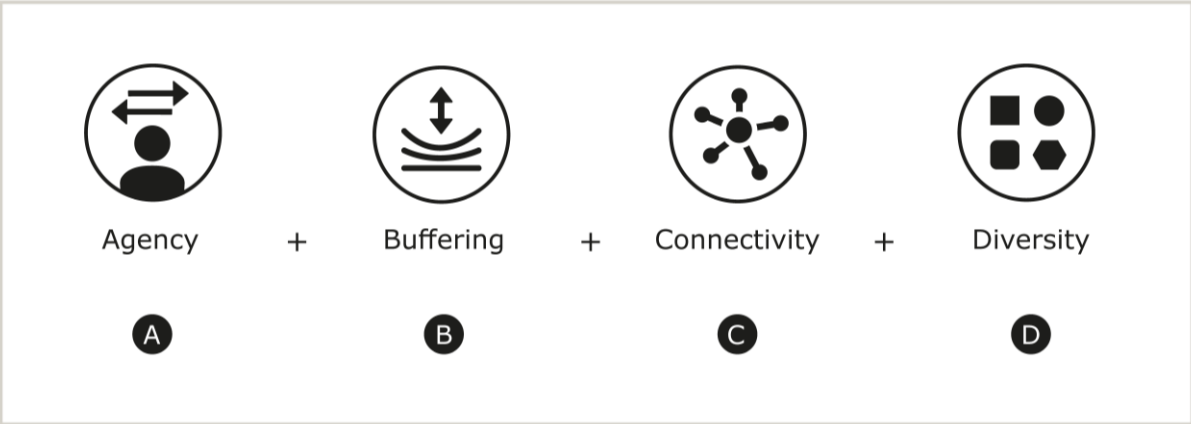

Figure 2 *The **ABCD** of food system resilience building*

The following section will examine current methods to assess food systems resilience. We will then develop a resilience assessment framework that leverages the **ABCD** properties for the evaluation and measuring of food systems resilience. We will also discuss a stylised case study involving a common intervention that demonstrates the use of our proposed framework. The paper will conclude with a discussion of the advantages and disadvantages of the framework.

3 Assessing food systems resilience

Let us consider a policy maker who is assessing the impact of an intervention on the resilience of a particular food system. Ideally, this policy maker would have ready access to a system that quantifies the current resilience of this food system and that can provide predictions for future resilience given certain interventions. A resilience researcher designing such a system would however face several serious challenges. The first of these challenges is the complex, multi-faceted nature of resilience itself (van Wassenaer, Oosterkamp et al. 2021): quantification requires researchers to go beyond intuitive understandings of resilience and to be more specific about what resilience means in a particular context. This requirement for further specificity is universally acknowledged within the resilience literature. For instance, Meerow et al. (Meerow, Newell et al. 2016) propose the 'Five Ws' to help stakeholders define resilience in any specific context, which we reformulate in the context of food systems in Table 1.

Table 1 *Meerow and Newelly's five Ws in the context of food systems*

#	W question	Food system specification
1	Resilience for **W**hom	Whose resilience, which groups (vulnerable or otherwise)? Think of actors or groups of actors at different scales, including consumers, producers, trading companies, local governments, minorities, etc. Note that for instance 'nature' may also be considered an actor.
2	Resilience of **W**hat to **W**hat	Minimum level of desired outcomes of food systems, what shocks/stressors? For example, the effects of changes in food prices may be different from those of weather extremes.
3	Resilience for **W**hen	Over what time scale is resilience evaluated? We may for instance consider recovery as soon as possible or across two or three decades.
4	Resilience for **W**here	What spatial scales are relevant? The resilience against weather extremes may be considered in the context of a village, a region, or even across multiple countries.
5	**W**hy resilience	You may be interested in resilience because of intended policy measures, or an investment.

This structured set of questions immediately suggests that there is not a single, unified understanding of food systems resilience: for example, different groups (**W**hom) can show different levels of resilience to different shocks and stressors (**W**hat). A best-case scenario would see the specification of all relevant answers to the questions above and assess resilience for each answer separately. However, this raises the question how these different forms of resilience should be evaluated *against each other*, especially since interventions might affect each resilience differently, leading to trade-offs. For instance, investing in the productivity of local smallholders might lead to consolidation of holdings between them, leading to further productivity increases of the remaining farmers because of scale benefits. This improves the resilience of local agricultural production and the remaining farmers but leaves the smallholders that have sold their farms in an uncertain situation. In other words, having acknowledged that multiple forms of resilience exist for each food system, we must contend with the fact that these forms of resilience are not easily summarised or added up, but instead imply difficult value judgments by the policy maker with regards to focus and prioritisation.

A second challenge lies in the quantification and measurement of resilience. Even when focusing on one set of answers to the questions in Table 1 (e.g., smallholder farmers in Bangladesh and their resilience against floods in the next decade), quantifying resilience is not straightforward. If the focus is on food security during and after the shock/stressor, one could for instance choose the maximum decrease in food security *during* or the level of food security that the system returns to *after* the shock. The commonly used 'return time' (Pimm and Lawton 1977), quantifies the time it takes the system to return to the pre-shock state. Again, this presents the policy maker with a set of nontrivial questions: does she care more about how bad food insecurity gets during the crisis, or about how long it takes for food security to be restored to pre-crisis levels?

The third challenge is to relate known food system properties to predictions of food systems performance during shocks/stress (resilience). Here again, the challenge is complexity, both of food systems and of resilience as an emergent property of food systems. Since resilience can only be measured after the occurrence of shocks/stressors, but policy makers require resilience assessment before shocks have occurred, resilience assessments often focus on (measurable) food system properties that are likely to be related to food security and resilience. Some food system properties convey resilience specific to one type of shocks (for instance, a dike protecting against a flood), while other properties provide resilience against a broader set of shocks (for example, the maintenance of local emergency food stocks protects against many types of shocks). Several resilience assessment indicator-based frameworks exist. For instance, Cabell and Oelofse (Cabell and Oelofse 2012) proposed 13 indicators for the assessment of agroecosystem resilience. Using indicators, some type of quantification can be obtained by having stakeholders assign discrete values - for instance, ranging from ‘0’ to ‘4’ (Jacobi, Mukhovi et al. 2018). Further reviews of metrics and indicators of resilience are provided by (Hosseini, Barker et al. 2016), although they are not always specifically aimed at agroecosystems. One particular *a priori* quantitative resilience metric is provided by Ulanowicz et al. (Ulanowicz, Goerner et al. 2009) (see also (Van Voorn, Hengeveld et al. 2020)), where, based on the data of flows of information (i.e., money, crop volumes, water, etc.), an estimate is given of the capacity of a system to withstand a shock. This paper proposes an assessment framework based on the ABCD properties of resilient food systems, which can be understood as a categorisation of food systems properties (e.g., Connectivity being supported by the density of transport networks) that are relevant to food systems resilience. However, irrespective of the indicator framework that is used, the direct translation of indicators to resilience is impeded by the complexity of both food systems and resilience itself and is often predominantly qualitative, without obvious ways to combine/sum the contributions of different indicators and to evaluate potential trade-offs between the indicators.

A final challenge to the assessment of resilience in food systems are the data requirements of the measurement of the above-mentioned indicators. In many cases, relevant food systems properties could be measured in principle, but data are not readily available and difficult to measure in practice. For instance, financial savings are an obvious buffering property, and are in principle easy to measure, but in practice would require extensive interviews with the participants of a particular intervention. Other important food systems properties, such as the influence of gender relations on social status, are even more difficult to quantify and thus measure.

In conclusion, the assessment of the resilience of a food system is challenging because of the complex nature of both food systems and resilience itself. The food systems components do not add up to a single understanding of resilience in a straightforward manner, but instead present the policy maker with several trade-offs with respect to her or his priority in terms of groups, shocks, time scale, etc (see Table 1). We propose an assessment framework that leads to more clarity about these trade-offs and the most important food systems properties to consider when evaluating interventions.

4 An assessment framework of food system resilience

Considering the complexity and limitations of measurement approaches that are currently available, we propose a framework for the ex-ante assessment of the effects of interventions on food system resilience. **Figure 3** illustrates the five steps that constitute this framework:

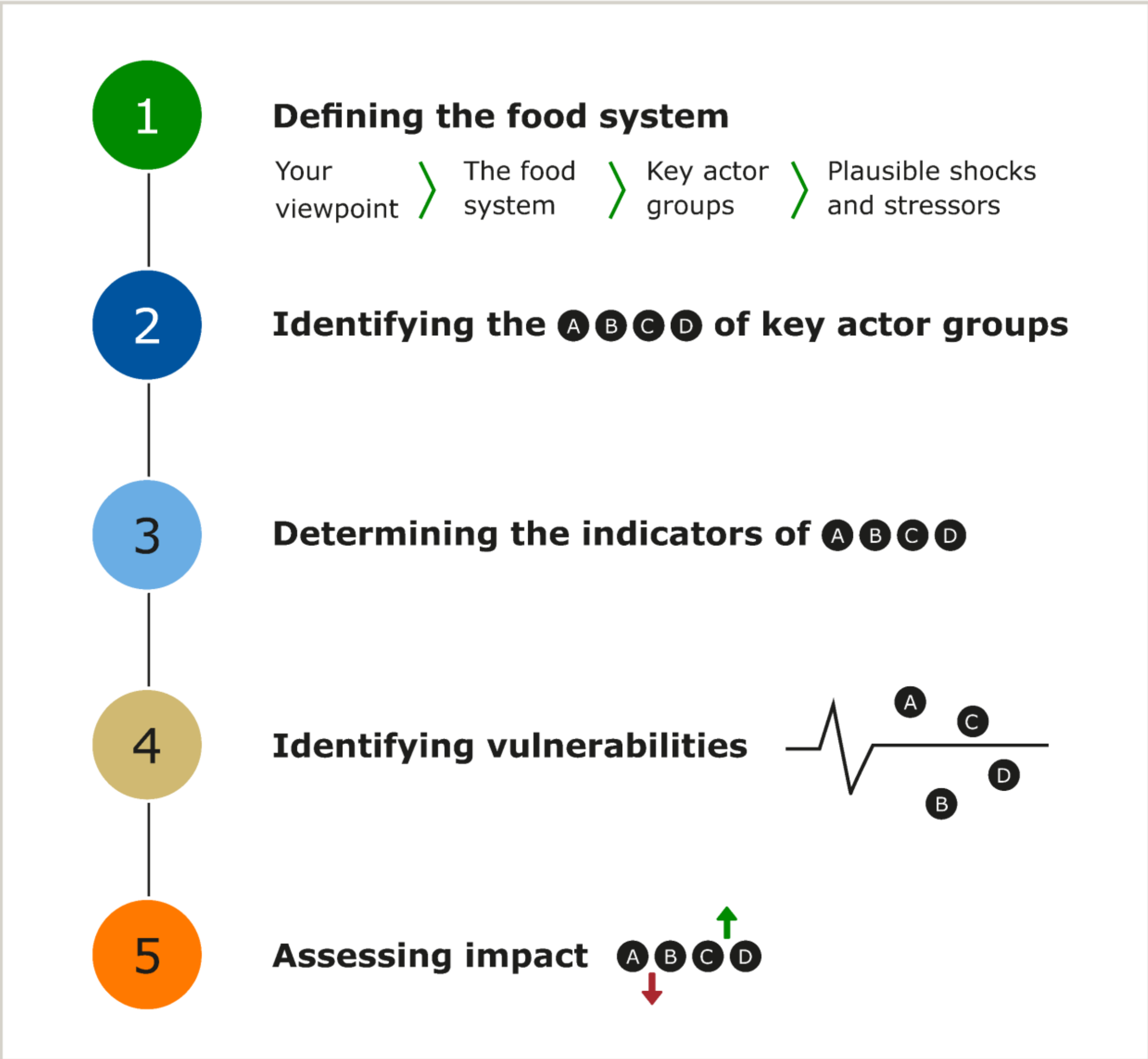

Figure 3 *Overview of the Resilience Assessment Framework*

Step 1 addresses the general delineation of the food system and its vulnerabilities to shocks, stressors and abrupt changes. To structure this inquiry, we propose four sub-questions that address key elements for system analysis and vulnerabilities:

a. What is the point of view from which the food system is evaluated? The perspective one has on a food system shows which components and scales are emphasised most and provides a starting point in describing it. A food system description and perspective will differ between smallholders and an entire country, for example. After having defined the perspective the food systems outcomes are defined as outlined above, such as: What does food security imply in this context? Which costs and benefits are addressed, and how? To what extent are livelihood stability and environmental sustainability considered by the different stakeholders?

b. What are important components and actors (and groups thereof) in the food system? What are the connections between these components? How is the food system bounded in time and space? These boundaries include physical boundaries (countries, regions) and the groups of actors that are included (such as vulnerable groups), but also the extent of relevant trade relationships. For example, rural villagers in a low- or middle-income country might predominantly depend on local food production, supplemented by trade with neighbouring regions. In this case, the natural delineation of the food system is very local. On the other hand, food security for European citizens is supported by food production around the world. Their food system should, at the very least, include international commodity markets, but could exclude a detailed description of the individual production systems supporting these markets. This is because local shocks (in or outside of Europe) will naturally translate to price increases, which will be the most important transmission mechanism to food security under investigation.
c. Which actor groups are most vulnerable with respect to food system outcomes and who are most likely to be affected by the intervention? The inclusion of groups or subgroups that are *a priori* considered as vulnerable is recommended.
d. What are the potential shocks and stressors that are relevant or anticipated for this food system and its vulnerable groups? For example, the urban poor in many LMICs suffered from international price shocks during the 2007-2008 world food price crisis. Pandemics such as the COVID-19 have more effect on the livelihoods of labourers across the world, mainly because of travel bans and lockdowns and their effect on sectors such as tourism and hospitality.

Step 2 specifies the **ABCD** properties of the actor groups identified under question 1c. The case study in the following section illustrates this process further.

Step 3 identifies qualitative or quantitative indicators for the **ABCD** per actor group. For instance, average household savings is a direct measure of a financial buffer. Other **ABCD** properties, especially agency, are likely to be difficult to quantify – although proxies, such as average education level, might exist.

Step 4 identifies the vulnerabilities of the **ABCD** properties per actor group: an actor group composed of specific households can be considered more resilient if they score highly on more than one of the four **ABCD** properties. Groups might show a mixed score across these (e.g., households that are low in buffering but high in connectivity) and this mix will vary across groups within a food system. This emphasises the usefulness of focusing on groups within the food system and resisting the urge to assess resilience across the food system in an aggregated way.

Step 5 assesses the plausible impact of a particular intervention on the actor groups and the **ABCD** indicators identified in step 3. Changes in the resilience as expressed by the **ABCD** properties and indicators of actor groups can then be evaluated. From these changes, trade-offs, and synergies within and between actor groups can be highlighted and analysed. In most cases, this analysis will remain qualitative, as it will be exceedingly difficult to quantitatively predict the effect of interventions on the indicators of **ABCD** properties, even if these indicators are all quantitative themselves. Instead, policy makers can only rely on informed guesses to reason about potential trade-offs and synergies.

5 Applying the assessment framework

We illustrate the five-step framework through a case study, which focuses on forecasting the potential effects of a proposed policy measure to enhance the resilience of a food system. This case study is hypothetical and informed by the literature on crop insurance. It is intended to give more insight into how the framework will operate in practice, while refraining from too many specifics and details. We are currently planning applications to real-world projects, on which we will report in later publications.

5.1 The case study

The case study centres on a hypothetical proposal to introduce crop insurance to support smallholders in an LMIC. Crop insurance is applied in many different contexts, often in combination with microcredit schemes. Crop insurance mitigates the risk of production shocks for both the farmer and lender (supplying credit for inputs, such as fertiliser and high-quality seeds), and is therefore a direct strategy to improve resilience (in the form of buffering) of the smallholder. Furthermore, the availability of credit and insurance improves the productivity and profitability of smallholders by allowing them to focus on higher-risk (cash) crops. Therefore, we expect this intervention to have a wider impact on the food system than resilience alone. Our assessment of the intervention begins by defining the food system and resilience in this context (Step 1, see Table 2 for full details). We assume here that this intervention is initiated by a non-governmental organisation (NGO). Since crop insurance in combination with microcredit schemes both affect resilience and profitability, the NGO's aim can be either or both, but this must be specified *a priori* since it determines the viewpoint for this case study. The food system consists of smallholders, their trade partners (including other households that depend on their production), input suppliers and credit agencies; with the main relationship being financial (trade and credit) and social (kinship, social hierarchy within villages, gender). The boundaries of this food system are local, as we expect trade to more distant (i.e. international) partners to be of limited importance (but this can change depending on the exact food system under consideration). From the full list of actor groups, we select the smallholder households and the households that depend on the smallholders' production as the most vulnerable actor groups. These two will serve as the focus for subsequent analyses. We conclude step 1 by analysing potential shocks and stressors, which include in this case localised shocks impacting food production, including floods, heavy rainfall, and droughts.

Table 2 *Step 1: System definition Index-based crop insurance case study*

Step 1: System definition Index-based crop insurance case study		
a. Viewpoint	Viewpoint from which food system resilience is formulated, including brief description of case	A development agency supported by an impact investor introduces crop insurance to protect smallholders against common production shocks, improving resilience directly, but also promoting the cultivation of high-risk high-yield crops and thereby economic viability. In this case study, the focus is on the resilience effect.
b. Food system description	What are the components/actors, their relationships, and what bounds the food system?	Smallholders, trade networks, including local traders and their consumers. Region within an LMIC dominated by smallholders. Not including urban populations or foreign producers/consumers of food, because food is predominantly locally produced and consumed.
c. Vulnerable groups	Groups vulnerable under current conditions or whose resilience is affected by intervention	1. Smallholder households. 2. Households depending on food production by smallholders since both groups will struggle to source food if local food production decreases.
d. Relevant shocks/stressors	Shocks and stressors of interest (production/trade/pandemic/climate change)	Productivity shocks: i.e., droughts, floods and pests.

Step 2 (see Table 3) analyses the relevant **ABCD** properties for each actor group. The smallholder households' agency is, in this case, determined by their ability to develop their livelihoods, both in terms of farm productivity and in terms of off-farm employment. These factors are in turn influenced by their social status (including gender and position within social hierarchy i.e., caste). Their buffering capacity is formed by the food reserves they maintain, as well as livestock (both for consumption and for sell-off value during a crisis) and any financial reserves (savings). Their connectivity can be described by their local trade relationships, which, to a large degree, will overlap with social and family relationships. Finally, smallholders can diversify both in terms of their cropping systems and access to different off-farm employment opportunities. For the households that depend on the smallholders' food production, their agency consists of the different job opportunities they can access (due to education level and social factors) and, in the longer term, their ability to migrate if the local economic outlook is too weak. Their buffering capacity is limited to food reserves (but to a lesser extent than the smallholder's families, as they require cash surpluses to buy food reserves) and savings. In terms of diversity, they rely on the diversity of cropping systems *among* local smallholders, as well as the diversity of local job opportunities.

Table 3 *Step 2:* ***ABCD*** *properties per actor group*

Step 2: ABCD properties per actor group				
	Agency	**Buffering**	**Connectivity**	**Diversity**
Smallholder households	Opportunities for productivity development (investment), social status as a limiting factor	Own reserves (cash, livestock and food)	Local trade and social relationships	Off-farm income and crop diversity
Regional households depending on local production	Education and social factors enable job opportunities. Ability to migrate	Household cash/food stocks	Social relationships between households, trade with other communities, and large-scale trade	Diversity of local production across farmers and local job opportunities

Step 3 (see Table 4) Identifies indicators for each of the **ABCD** properties among each actor group. In some cases, such as for buffering, indicators will suggest themselves easily: savings can be expressed as the average savings holdings during the last year (or simply a point measure), livestock can be counted, and food reserves can be easily quantified. However, these quantities will be distributed, and it may be more appropriate to use a lower quantile as indicator of resilience rather than the mean/median of the distribution, because lower quantiles focus more on the buffering capacity of the most vulnerable households. For the agency of smallholder farmers, profitability is a proxy for a farmer's ability to invest in new technology. However, investment without education might lead to suboptimal outcomes, so it is also necessary for education to be already at a sufficient level, or for further education to be within reach. Connectivity can be expressed at various levels: social contacts are important for the distribution of information but are difficult to measure in practice. Trade contacts (which might to a large degree overlap with social contacts), could be expressed as the share of production that is traded and the distance to a market to indicate trade potential. It is important that this distance is expressed not only in distance but also in time units since poor road networks can cause even modest distances to become impractical for trade. For both smallholders and the households they trade with, the social capital aspect of connectivity can be recognised via the previous use of social relationships in food and other crises. Diversity for householders can be quantified by the numbers of crops within the cropping system, the number of distinct sources for off-farm income, and the share of off-farm income to total income. For the regional households (with limited agricultural activity), the diversity can be quantified similarly: both the number of different crops (but now evaluated *across* smallholders) and the number of different job opportunities (which might be different than the number of different off-farm income sources for smallholders). It is important to note that, although these indicators could potentially be easily monitored (by surveys), it is far from trivial to combine them into a single composite resilience indicator, or even an indicator for each single **ABCD** property – as it would be difficult to objectively weigh each indicator component against other components. Instead, these monitors should be used as a benchmark against indicators for other food systems and to monitor change during and after the intervention.

Table 4 *Step 3: Indicators of the **ABCD** properties for each actor group*

Step 3: Indicators of the ABCD properties for each actor group				
	Agency	**Buffering**	**Connectivity**	**Diversity**
Smallholder households	Profitability/acre, time to travel to agricultural education centre	Average savings and lowest quintile of savings, livestock, food reserves	What % of production is traded and to whom (only one-on-one, or one-to-many and many-to-one?), distance to market (in space and time), prior use of social relations in food crises	Off-farm income, number of available sources for off-farm income, number of crops in cropping system (/year)
Regional households depending on local production	Years of education, social status, gender	Average and lowest quantile of savings and food reserves	Prior use of social relations in food crises, existence of trade between other communities (villages), and larger production/trade centres	Number of different crops across farmers (/year), number of different job opportunities

Step 4 (Table 5) assesses the current state of the food system and how **ABCD** properties contribute to the resilience of each actor group. While step 2 identified how the **ABCD** properties could potentially contribute to resilience, step 4 analyses to what extent these properties are present and whether their contribution to resilience materialises. For instance, smallholders can buffer by maintaining their own food reserves. However, if the smallholders are forced to sell their products immediately after harvesting to settle debts (as we assume here), there is little scope for financial or food buffers. In general, the low profitability of smallholders limits their options to invest and improve future outcomes (agency). Moreover, to a significant extent smallholders depend on their own food production for their income, which makes them less diversified with regards to local production shocks. On a positive note, the social capital in these communities is often high, which creates some relief during food crises. Plus, smallholders traditionally have well-diversified cropping systems, which protects against some of the risk of crop failures. For the regional households depending on the smallholders' production, step 4 leads to broadly comparable results.

Table 5 *Step 4: Vulnerabilities of each actor group for each **ABCD** property*

Step 4: Vulnerabilities of actor groups for each ABCD property				
Green = positive contribution			Red = negative contribution	
	Agency	**Buffering**	**Connectivity**	**Diversity**
Smallholder households	Low profitability limits other options	Low reserves	Social relationships protect food security during crises	Diverse cropping systems protect against local shocks Large dependence on own food production
Regional households depending on local production	Low education limits employability	Low reserves	Social relationships protect food security during crises The trade network is local, so high vulnerability against local production shocks	Diversity of crops across farmers Low diversity in job opportunities

Finally, step 5 (Table 6) assesses the intervention's impact on each component (outlined in Table 3, Table 4 and Table 5). First, it should be noted that there will be some components on which the intervention is likely to have no impact. For instance, the introduction of crop insurance to smallholders is not likely to affect the trade network – at least initially – of the regional households that depend on the smallholders' production. Then, there is the target of the intervention, which, in this case, is the buffering capacity of the smallholders. The effective introduction and application of crop insurance buffers against the impact of local production shocks. We also expect this buffer to stimulate farmers to be less risk averse and invest in higher-yielding crops, since their losses are better covered following a production shock. This improves profitability (positively affecting their future agency) and could also improve their other reserves. However, a review of the results of crop insurance schemes in LMICs (Marr, Winkel et al. 2016) shows that, in some cases, this intervention type also leads to unintended consequences which affect resilience negatively. For instance, they have shown that relatively wealthy farmers are more likely to buy crop insurance than their poorer counterparts. Since using crop insurance might lead to more profitability, this increases inequality between farmers not only during a production shock (because of diverse levels of protection), but also in general. Therefore, the intervention might lead to a decrease in agency and buffering capacity for the most vulnerable households within the smallholder actor group. Additionally, increasing economic inequality might also threaten social trust within this group, leading to reduced capacity to lean on social capital during crises. We predict this intervention's impact on the regional households that depend on the smallholders' production to be limited to the expectation that food will become more available (because of productivity increase) and cheaper, which should increase their buffering capacity.

Table 6 *Step 5: Assessment of the impact of the intervention of the **ABCD** properties for each actor group*

<table>
<tr><th colspan="5">Step 5: Assessment of the impact of the intervention of each of the ABCD properties for each actor group</th></tr>
<tr><th colspan="2">Positive change</th><th colspan="2">Negative change</th><th>No change</th></tr>
<tr><th></th><th>Agency</th><th>Buffering</th><th>Connectivity</th><th>Diversity</th></tr>
<tr><td rowspan="3">Smallholder households</td><td rowspan="2">Improved profitability</td><td>Crop insurance buffers against production shocks</td><td rowspan="3">Social relationships might become strained by increased inequality</td><td rowspan="2">Diverse cropping systems protect against local shocks</td></tr>
<tr><td>Potential to improve reserves</td></tr>
<tr><td>Uptake of insurance by richer farmers increases inequality</td><td>Uptake of insurance by richer farmers increases inequality and thereby ability to build reserves</td><td>Large dependence on own food production</td></tr>
<tr><td rowspan="2">Regional households depending on local production</td><td rowspan="2"></td><td rowspan="2">More/cheaper food makes it easier to build reserves</td><td>Social relationships protect food security during crises</td><td>Diversity of crops across farmers</td></tr>
<tr><td>Trade network is local, so high vulnerability against local production shocks</td><td>Low diversity in job opportunities</td></tr>
</table>

Steps 1-5 applied the **ABCD** properties to assess the impact of a direct intervention on resilience (crop insurance) of two vulnerable actor groups. The relationships within and between these groups were shown to be crucial in assessing this impact, particularly with regards to increased inequality between smallholders caused by the diverse levels of crop insurance adaptation. This is not to say that we would advise against such a crop insurance scheme: under the right conditions (price and pay-out conditions), it has proven to be a powerful tool in increasing the productivity and profitability of smallholders. But this analysis, partially inspired by (Marr, Winkel et al. 2016), shows that checking the conditions under which even the poorest of smallholder farmers would be willing to buy insurance, or other policies in combination with crop insurance that directly help this group, is crucial for success. Our analysis has highlighted the immediate impact of the introduction of crop insurance (its buffering capacity) on resilience, but also, and more importantly, the indirect effects – both positively (the availability of cheaper food for the regional households that depend on smallholders' production) and negatively (the potentially detrimental effect of increased economic inequality on social capital). The assessment framework affords a more complete view on resilience, because it guides policy makers through a structured set of steps to describe the food system, the actor groups under consideration and their relationships, and the resilience properties that are important in this context.

6 Discussion and conclusions

The resilience of food systems has become an important consideration for policy makers in governments, investors, NGOs and other actors. Therefore, interventions to enhance resilience of the food system, or impact it in other ways, will become increasingly assessed for their effects. Universally applicable methodologies are required to evaluate the expected impact of interventions on resilience. Forecasting, assessments, and evaluation are, however, not straightforward when applied to food systems. These are being increasingly understood as complex systems, for which the scope for accurate prediction and forecasting is limited. In addition, resilience is an emergent property and depends heavily on the many interdependencies between components, actors, and drivers in socio-ecological environments. These interdependencies often result in trade-offs and synergies associated with interventions. In brief, some components will be enhanced but others may weaken, as there will be winners and losers among food system actors. Like predictions and forecasts, the evaluation of interventions is not straightforward. This is for an important part because the resilience of individual components and actors cannot be trivially added up to the level of the overall food system. Simply put, we cannot compare apples and oranges – at least, not without making some assumptions that need to be made explicit.

In this paper, we develop an assessment framework for food system resilience that is formulated around the four **ABCD** properties. By grounding the analysis in a detailed description of the food system, its vulnerabilities and key actor groups, it is possible to analyse the four properties using qualitative and, if possible, quantitative indicators. This enables an analysis of the plausible effect of an intervention by actor group, and highlights inevitable trade-offs and synergies associated with the intervention. It is also clear from this analysis that trade-offs exist between **ABCD** properties *within* groups, *between* groups and in time. For instance, interventions that aim to increase cash crop production of smallholders might temporarily reduce smallholders' resilience, because, during a shock, they can resort to their own food production for consumption to a lesser degree. This effect will be especially pronounced early in the intervention when production efficiency is not high enough to be competitive on the global market. Once competitiveness is optimised, the focus on cash crop production might have genuinely increased the average wealth of each smallholder family, which, in turn, provides them the opportunity to buffer against shocks in other ways. By then, their resilience has been enhanced by the intervention.

The assessment framework will, in practice, only be partially quantitative at best. Some, if not all, of the **ABCD** properties may be difficult to quantify, because data is lacking and expensive to measure or impractical to obtain, or because of conceptual limitations. For instance, the buffering property for smallholders can be easily quantified in terms of their financial and other assets, but these data are often missing. Instead, the assessment framework relies on qualitative assessments, which should always be treated with caution. Small trials of the intended intervention in varying contexts and qualitative, participatory methods are the best approach to gain confidence in the outcome of the assessment framework and adjust it when necessary.

Even though the proposed assessment framework has its limitations, compared to current practice, it provides much deeper insights into the effects of an intervention on food system resilience. Providing disaggregated views on what and who benefits from an intervention encourages greater evidence-based decision-making by policy makers, investors, and other key stakeholders: it may lead to the identification of unwanted results from interventions, and when different interventions are compared, may also lead to the ranking of interventions with respect to effect on resilience. Moreover, it strengthens the development narrative, which used to be biased towards rendering systems more efficient. As we now know, this can occur at the expense of resilience. Balancing between food system efficiency and resilience may well be one of the most prominent trade-offs of future interventions.

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POLICY PAPER 2022-082

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