Resilience in Food Systems

The case of *tef* in Ethiopia

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Key messages

- Well-functioning food systems are essential to ensure that people do not suffer from malnutrition.
- Food systems must be resilient to shocks in order to minimize the negative impacts on food and nutrition security, environmental quality and social well-being.
- The resilience of food systems can be analyzed by breaking them down into individual value chains of commodities.
- Our project has developed an initial set of guidelines which proposes a suite of methods, techniques and tools to assess and build resilience in food systems. They are structured into four iterative steps, which are: 1) problem identification and framing, 2) definition of the system, 3) resilience assessment, and 4) interventions for resilience building.
- Understanding the resilience of individual value chains is a crucial first step for assessing entire food systems.

Challenged food systems

Well-functioning food systems are essential to ensure that people do not suffer from malnutrition. Today, malnutrition is visible both in form of undernutrition (including hunger and inadequate nutrition) and overnutrition (including overweight and obesity).

Among many institutions, the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) advocate improving the functioning of food systems in order to provide sufficient, safe, high quality and accessible food for all people. However, the increased occurrence of shocks (unexpected disturbances) is making it increasingly difficult in all parts of the world to provide food and nutrition security for everyone and at all times.

A shock – for example, in the form of a bad harvest that is caused by a plant disease – not only directly impacts the affected farmers, but also leads to indirect consequences for all the actors involved (e.g., input suppliers, processors, retailers, and consumers) who are associated with the affected crop. In other words, a shock creates challenges which affect the proper functioning of many elements of a food system. Hence, food systems must be resilient and able to anticipate and respond in a timely manner to shocks in order to minimize the negative impacts on outcomes such as food and nutrition security, environmental quality and social well-being.

> "The increased occurrence of shocks is making it more and more difficult to provide food and nutrition security for everyone at all times"

In our research project on "Enhancing Resilience in Food Systems," a flagship project of the World Food System Center at ETH Zurich, we define food system resilience as "the capacity over time of a food system and its units at multiple levels to provide sufficient, appropriate, and accessible food to all, also in the face of various and even unforeseen disturbances."[1] This definition takes into account the complexity of food systems as well as growing pressures from various risks. Climate change, political tensions, sudden economic changes are just a few examples of risks that can that can trigger shocks which ultimately affect the functioning of food systems. Addressing this complexity requires an understanding of the human/environmental interactions at multiple levels and scales[2–4] and a consideration of the potential feedback effects that result in complex and often non-linear dynamics.[5, 6] It also calls for the inclusion of emerging trade-offs of one set of services (for example, food production) at the cost of another (for example, cleaner water).[7–9] Dealing scientifically with the complexity of food systems calls for the adoption of holistic research approaches which reflect the interdisciplinary and systemic nature of the problem. Systems science offers a large range of tools that make

TABLE 1: Structure of guidelines

#	Stage	Steps
1	Problem identification and framing	> Literature review
		> Interviews, consultation
2	Definition of the system	> Value chain analysis
		> Drivers of change
		> Material flow analysis
		> Stakeholder analysis
3	Resilience assessment	> Data collection (survey, interviews, secondary data)
		> Data analysis
4	Interventions for resilience building	> Formulation of interventions based on resilience assessment
		> Formulation of interventions through stakeholder consensus (workshops)

is possible to assess complexity in food systems.[3] Another aspect to be considered in this discourse is the linkage between sustainability and resilience, which are seen as distinct concepts but which are at the same time complementary, as they each support the development of greater strength within systems for coping with unexpected changes.[1]

"Our long-term goal is the development of a comprehensive resilience framework for assessing and building resilience within food systems"

Towards a resilience framework for food systems

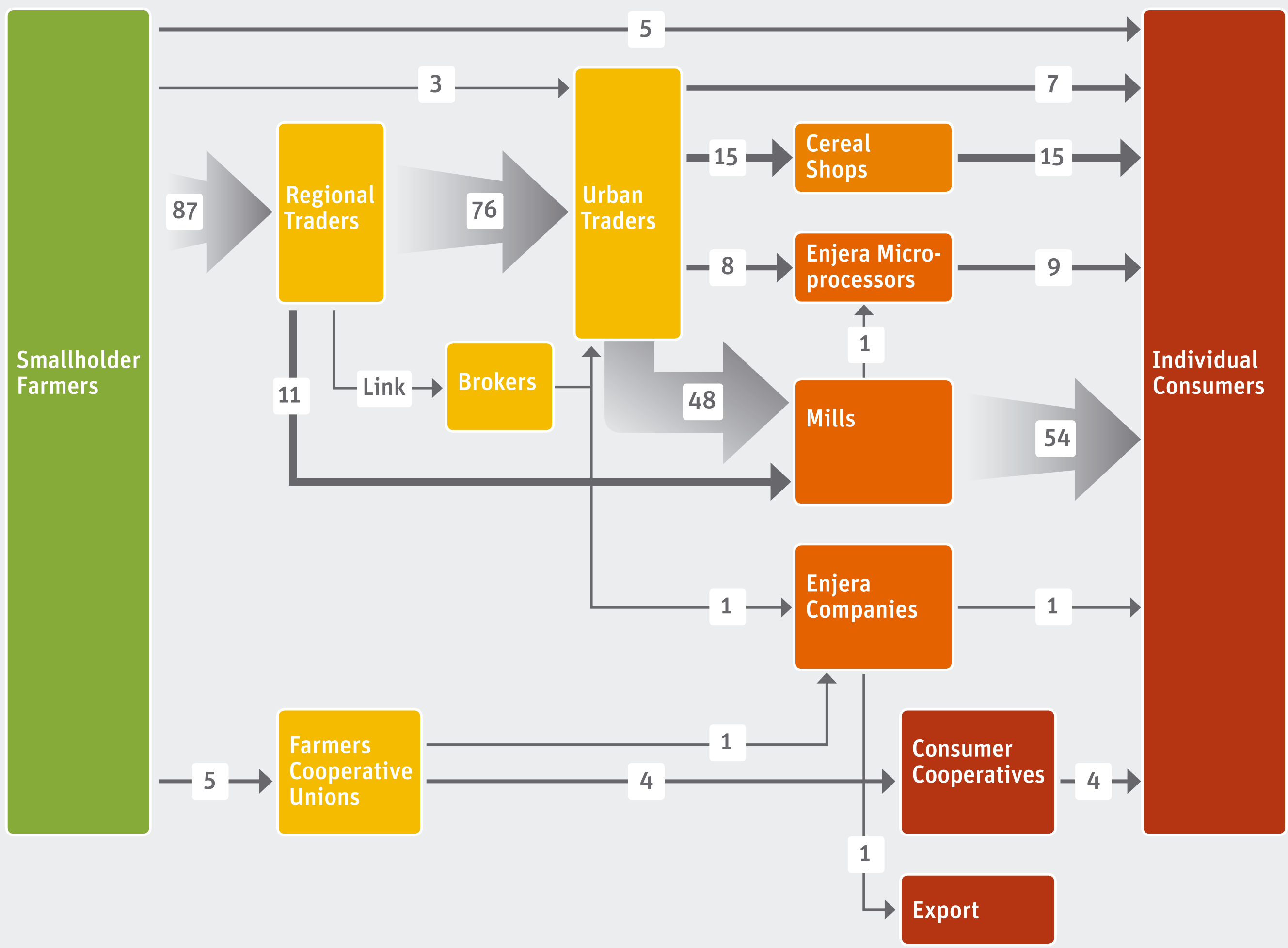
To assess and enhance resilience in food systems, we start by disentangling their complexity and breaking them down into individual value chains of commodities. These value chains constitute subsets of food systems. Throughout the resilience assessment process, we remain aware of the fact that food systems include multiple value chains that are interconnected, and that those value chains provide multiple outcomes.[1] Analyzing individual food value chains does, however, serve our primary objective, which is to understand what kind of indicators (e.g., availability of stocks, response mechanisms against shocks, etc.) define resilience in food systems. This supports our long-term goal, which is the development of a comprehensive resilience framework for assessing and building resilience within food systems.

Currently, our project has developed an initial set of guidelines which synthesize the relevant literature and propose a suite of methods, techniques and tools to assess and build resilience in food systems. The guidelines are designed to help governmental and non-governmental stakeholders to assess resilience in food systems. They are structured into four iterative steps, which are: **1)** problem identification and framing, **2)** definition of the system, **3)** resilience assessment, and **4)** interventions for resilience building (**see Table 1**). In order to assess food system resilience (**step 3**), we draw on a set of indicators and corresponding analytical questions that cover the major attributes characterizing systems with a high level of resilience. These include: buffering capacity; diversity; connectivity; capital (economic, financial, environmental, social, physical); exposure to pressure; profitability; self-organization; governance capacity; transformability; transparency and information availability; learning capacity; and equitability.[1]

These guidelines account for realities in an operational context, including situations with low availability of data and

The *tef* value chain

FIGURE 1: Material flows for the post-production steps. Material flows in % of total marketed *tef.*



Source: Authors' calculations based on [12, 13] and expert interviews.

resources. We do not propose a single procedure with fixed methods, but rather allow for differences in context, availability of data and expertise, and engagement of stakeholders. Hence, our guidelines consist of a stepwise approach ensuring that important issues are systematically identified and analyzed, while supporting a flexible combination of appropriate qualitative and quantitative methods.

Case Study: Resilience of the *tef* value chain in Ethiopia

The aforementioned guidelines have been recently applied to the *tef* value chain in Ethiopia in partnership with the Ethiopian Institute of Agricultural Research in Debre Zeit. In a first step of the guidelines, we framed the *tef* value chain. *Tef* is a primary staple food in Ethiopia. It is deeply rooted in Ethiopian culture as a preferred food ingredient for making *enjera*, a fermented flatbread present in most Ethiopian meals (**Figure 1**). It has great nutritional value (see **Table 2**) and is suitable for people with gluten intolerance.[10]

In the second step of the guidelines, we looked at the structure of the *tef* value chain. Until recently, 99% of the global *tef* production took place in Ethiopia, making the *tef* value chain localizable.[14] The export of non-processed *tef* has been banned since 2006 in an attempt to keep domestic prices low,[14] although with little effect, as domestic *tef* prices continue to rise every year due to increasing demand from a growing urban population.[13] Around 36% of *tef* has been marketed in 2013[15] – hence it can be regarded as a food security crop; however, the share of *tef* that is marketed is growing year by year. So far, the majority of *tef* is consumed by subsistence farmers, especially by those located in remote areas of Ethiopia. For the 36% of *tef* which is marketed, regional traders collect 87% from farmers. From the regional traders, the majority of *tef* goes to urban

TABLE 2: Nutritional characteristics of *tef* grain

Tef grain (per 100 g)		
Energy	kcal	367
Protein	g	13.3
Total lipid (fat)	g	2.38
Ash	g	2.37
Carbohydrate, by difference	g	73.13
Fiber, total dietary	g	8
Sugars, total	g	1.84
Calcium, Ca	mg	180
Iron, Fe	mg	7.63
Magnesium, Mg	mg	184
Phosphorus, P	mg	429
Potassium, K	mg	427
Sodium, Na	mg	12
Zinc, Zn	mg	3.63
Copper, Cu	mg	0.81
Manganese, Mn	mg	9.24
Selenium, Se	mg	4.4
Thiamin	mg	0.39
Riboflavin	mg	0.27
Niacin	mg	3.363
Pantothenic acid	mg	0.942
Vitamin B_6	mg	0.482
Choline, total	mg	13.1
Betaine	mg	2.3
β-Carotene	µg	5
Vitamin A	IU	9
Lutein + zeaxanthin	µg	66
Vitamin E (α-tocopherol)	mg	0.08
β-Tocopherol	mg	0.02
γ-Tocopherol	mg	5.04
δ-Tocopherol	mg	0.07
Vitamin K (phylloquinone)	µg	1.9
Lipids		
Fatty acids, total saturated	g	0.449
Fatty acids, total monounsaturated	g	0.589
Fatty acids, total polyunsaturated	g	1.071
Amino acid composition	g	12.597

Source: USDA National Nutrient Database for Standard Reference (2015)

Tef is also native to Ethiopia, making it more resistant to local pests and locally occurring diseases.[11] Compared to other major food staples, such as wheat and maize, *tef* can better sustain extreme heat and water-logging.

Enjera (Ethiopian flatbread) made from *tef*

traders, who then distribute it among various mills, *enjera* processors and cereal shops before it reaches the consumers. The consumers then either make *enjera* themselves from *tef* flour or else buy the ready-made *enjera*. The demand for ready-made *enjera* is growing rapidly in urban areas due to lifestyle changes and the associated need for convenience products.

In line with the third step of the guidelines, we assessed the ability of different stages of the *tef* value chain to deal with shocks. Based on a literature review, interviews (n=57) with actors from all stages of the value chain, and available secondary data, scores were assigned qualitatively (**Table 4**) for each resilience attribute (**Table 3**).

Key findings are as follows:

- The supply system for unimproved inputs (seeds and traditional farm implements) is more resilient than the one for improved inputs (fertilizer, pesticides, improved seeds and farm implements). Since unimproved seeds are produced by the farmers themselves, they are widely available, and are used by around 90% of all farmers. Improved inputs are relatively expensive, are supplied by only a handful of providers, and are not widely available.
- Although *tef* is resistant to extreme weather events (e.g., drought, water-logging) and is little affected by diseases, its production contributes to soil degradation (extremely fine seedbed required) and relies on extensive use of fertilizer. Even with high use of fertilizer, *tef* yields (between one and two tons per hectare) are still comparatively low compared with other (food security) crops.
- There are a large number of small, diversified businesses which produce *enjera* products. Big *enjera* producers are rare. Despite a growing availability of *tef*-based *enjera*, especially in urban areas, it is gradually becoming more expensive due to rising prices, making it less and less affordable for medium- and lower-income households.
- Overall, the *tef* value chain suffers in all stages from a

TABLE 3: Interventions to build resilience against droughts (numbers show priorities)

Intervention	Process						
	Input supply	Production			Trade	Processing & Retail	Consumption
		Farmers	Cooperatives	Experts			
Alternative income sources	1	4	1	4		7	1
Savings	3		2	2		3	5
Stocks		1		3		1	2
Insurance		2			2		4
Water harvesting techniques	7	5	3	5			
Drought resistant varieties		3	4	1			
Government support					3	5	3
Early warning systems					1	4	6
Self-organisation and trust	4					2	
Ability to express diverse opinions	5					6	
Promotion of improved technology	6						
Infrastructure quality	2						

lack of information and capacity to evolve. This is widely attributed to the dominant role of the government. For example, the government largely runs the improved input supply system as well as the information flow to farmers through its own extension services. Furthermore, a lack of available financial capital and insurance solutions hampers the ability of all actors across the *tef* value chain to transform themselves into more shock-resistant entities.

- On the positive side, the endemic, nutritious and profitable characteristics of *tef* make it a highly suitable commodity to be produced, processed and sold both within and outside Ethiopia.

Following the resilience assessment, the guidelines aim to develop interventions for building resilience. For this, stakeholders (n=26) across the *tef* value chain were invited to participate in a workshop to discuss how the *tef* value chain could become more resilient to shocks, in particular a drought scenario.

Interestingly, experts and farmers thought similarly about the type of interventions that would increase the resilience of the *tef* production. However, experts prioritized introducing drought-resistant varieties, whereas farmers saw the provision of stocks and insurance solutions as primary needs for building up resilience. This example highlights how consulting directly with relevant stakeholders leads to contrasting conclusions compared to what scientists and governmental actors may think are suitable interventions for building resilience. It also shows that interventions need to be tailored to particular stages of the value chain.

"Stakeholders across the *tef* value chain were invited to participate in a workshop to discuss how the *tef* value chain could become more resilient to shocks"

Next steps and way forward

Understanding the resilience of individual value chains is a crucial first step for assessing entire food systems. Apart from looking at *tef*, we are also currently assessing the resilience of the cocoa value chain in Ghana. In this case, we are dealing with a cash crop, which requires a different approach and understanding of food systems resilience. Next steps also include studies in Switzerland on key value chains, such as milk, beef, potato, etc. Once we have applied our guidelines to a number of case studies in very different contexts, we expect to know better what kind of indicators are needed to a) understand individual value chains and b) obtain insights into how they interact with each other from a systems perspective. This will support the development of a quantitative resilience framework for food systems in the coming years.

Such a framework must look at what kind of trade-offs and synergies arise between various food system outcomes, and between food system outcomes and resilience. For instance, do

TABLE 4: Resilience scores for all stages of the *tef* value chain. Orange is very low, yellow is low, light yellow is medium, light green is high, dark green is very high.

Attribute	Value chain step					
	Improved inputs	Unimproved inputs	Production	Trade	Processing & Retail	Consumption
Buffering capacity	Orange (very low)	Dark green (very high)	Yellow (low)	Light yellow (medium)	Light yellow (medium)	Yellow (low)
Environmental capital	Yellow (low)	Light yellow (medium)	Orange (very low)	Light yellow (medium)	Light yellow (medium)	Light green (high)
Connectivity	Orange (very low)	Dark green (very high)	Light yellow (medium)	Yellow (low)	Light green (high)	Dark green (very high)
Diversity	Orange (very low)	Dark green (very high)	Dark green (very high)	Light yellow (medium)	Dark green (very high)	Dark green (very high)
Equitability	Yellow (low)	Light green (high)	Yellow (low)	Light yellow (medium)	Light green (high)	Light yellow (medium)
Exposure to pressure	Light yellow (medium)	Light green (high)	Light green (high)	Light green (high)	Yellow (low)	Light green (high)
Governance capacity	Light yellow (medium)	Light yellow (medium)	Light yellow (medium)	Light green (high)	Light yellow (medium)	Light yellow (medium)
Information, learning	Light yellow (medium)	Light yellow (medium)	Orange (very low)	Orange (very low)	Yellow (low)	Yellow (low)
Profitability & financial capacity	Orange (very low)	Light green (high)	Dark green (very high)	Dark green (very high)	Light yellow (medium)	Orange (very low)
Self-Organization	Yellow (low)	Dark green (very high)	Light yellow (medium)	Light green (high)	Light green (high)	Light green (high)
Transformability	Orange (very low)	Light yellow (medium)	Light yellow (medium)	Yellow (low)	Light yellow (medium)	Yellow (low)

possible interventions actually achieve the desired effects? Are food systems flexible enough to manage sudden and frequent changes of external conditions, such as impacts of climate change, changes in nutrient cycles, and social and political disruptions? Such questions are absolutely critical to ensure food and nutrition security for a growing global population in the face of mounting and combined shocks.

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