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The U.S. Government's Global Hunger & Food Security Initiative

A Framework for Resilient Seed Systems

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Feed the Future Consortium Partners in the Feed the Future Global Supporting Seed Systems for Development activity:

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ABBREVIATIONS AND ACRONYMS

BASF	Badische Anilin- und Sodafabrik
COP	Conference of the Parties
EGS	Early Generation Seed
NGO	Non-governmental Organization
QDS	Quality Declared Seed
USAID	United States Agency for International Development

1. INTRODUCTION

USAID defines resilience as 'The ability of people, households, communities, countries, and systems to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth. Put simply, resilience is the ability to manage through adversity and change, without compromising future well-being' (USAID, 2022). This paper addresses resilience at the level of seed systems. The framework presented here draws heavily on the market systems resilience framework developed by Downing et al. (2018), along with existing frameworks and principles for seed system resilience, as summarized in **Annexes 1 - 6** and described below. It is expected that the framework will be further developed and refined over time; as such, the framework presented here can be considered as work in progress.

Seed system resilience is important for seed security and hence food security in the face of climate change and other shocks and stressors. If a seed system is resilient, then farmers will be able to access appropriate seed for planting under changing conditions (e.g., due to climate change, environmental degradation/recovery, etc.) and in times of protracted crisis. A resilient seed system can withstand and/or adapt and recover from the effects of shocks and stressors. Resilience is important because climate change is leading to changes in temperature, rainfall, and seasonal patterns, which all impact farming systems, crop pests and diseases, and the types of crops and varieties that can be cultivated in different areas. Also associated with climate change is the growing frequency and severity of adverse weather-related events such as drought, floods, and cyclones. Agricultural systems are also affected by economic shocks caused by currency fluctuations, changes in global markets, fuel price rises, etc. by impacting the cost of inputs as well as the price of outputs and the nature of market demand, often affecting farmers' choices as to which crops and varieties to plant. Finally, conflict, insecurity and displacement impact rural communities and farmers' planting choices. A seed system that can absorb, adapt, or transform in the face of long-term trends and/or short-term shocks enhances both seed security and food security for rural populations.

Much of the literature on resilience refers to households or communities rather than systems. More recently, academics and others involved in applied development work have explored the notion of resilience in relation to market systems (Downing et al., 2018) and food systems[1] (e.g., Tendall et al., 2015; Béné, 2020; van Uffelen et al., 2021). At a systems level, resilience has been defined as 'The capacity of the system to marshal and allocate available resources, be they public or private, community or national, to respond to a shock or stress regardless of its nature' (Downing et al., 2018). Food system resilience refers to the 'capacity of food systems to maintain functionality, recover from adverse effects and, ideally, to reach a better state despite shocks and stressors, be they conflict, and environment based, or health and economic in nature' (van Uffelen et al., citing UN, 2020). Seed system resilience is defined here as the ability of a seed system to maintain functionality, and to withstand, adapt and recover from the effects of shocks and stressors in a manner that, ideally, helps to reduce chronic vulnerability and facilitate inclusive growth. The three key functions of a seed system are: (i) variety development and management; (ii) seed production; and (iii) seed dissemination (**Figure 2**). This definition of seed system resilience is further elaborated below.

There are two key differences between system-level resilience and resilience at the levels of households or communities. First, the many interconnections within and between different actors and different value chains within a system create potentially powerful 'ripple effects' or feedback loops (Downing et al, 2018; Béné, 2020). Not only does the initial shock impact on certain actors within a system, but the responses of these actors that are triggered by the initial shock then ripple through to other connected actors. The complexity of

[1] The Conference of the Parties (COP) 28 held in the United Arab Emirates in late 2023 has also focused attention on resilient food systems; 134 countries signed the COP28 UAE Declaration on Sustainable Agriculture, Resilient Food Systems, and Climate Action.

the connections and dependencies between and among actors within a system are such that these ripples or feedback can create changes that are not only unpredictable but might have unintended consequences, e.g., where some actors might benefit, while others (or even the whole system) might be weakened (ibid.).

Second, it is also necessary to understand the system biases that shape the way a system self-organizes in response to a shock or stress (Downing, 2018). These system biases or 'mental models' include social and cultural norms, and conscious or unconscious beliefs and values that influence loyalties, behaviors, relationships, and other actions. One example would be gender biases. Within systems thinking, such biases are known as 'slow-moving variables'; they are located at the bottom of the systems iceberg (**Figure 1**), and they are the most difficult to change, yet also the most transformative when they do change (ibid.). In contrast, 'fast-moving variables' are located at the top of the systems iceberg; they change more frequently (e.g., changes in daily sales transactions), but they need to be tracked over time to determine whether or not the system itself is changing. **Figure 1** illustrates how different types of changes (e.g., reactive, transformative, etc.) take place at different levels within a system.

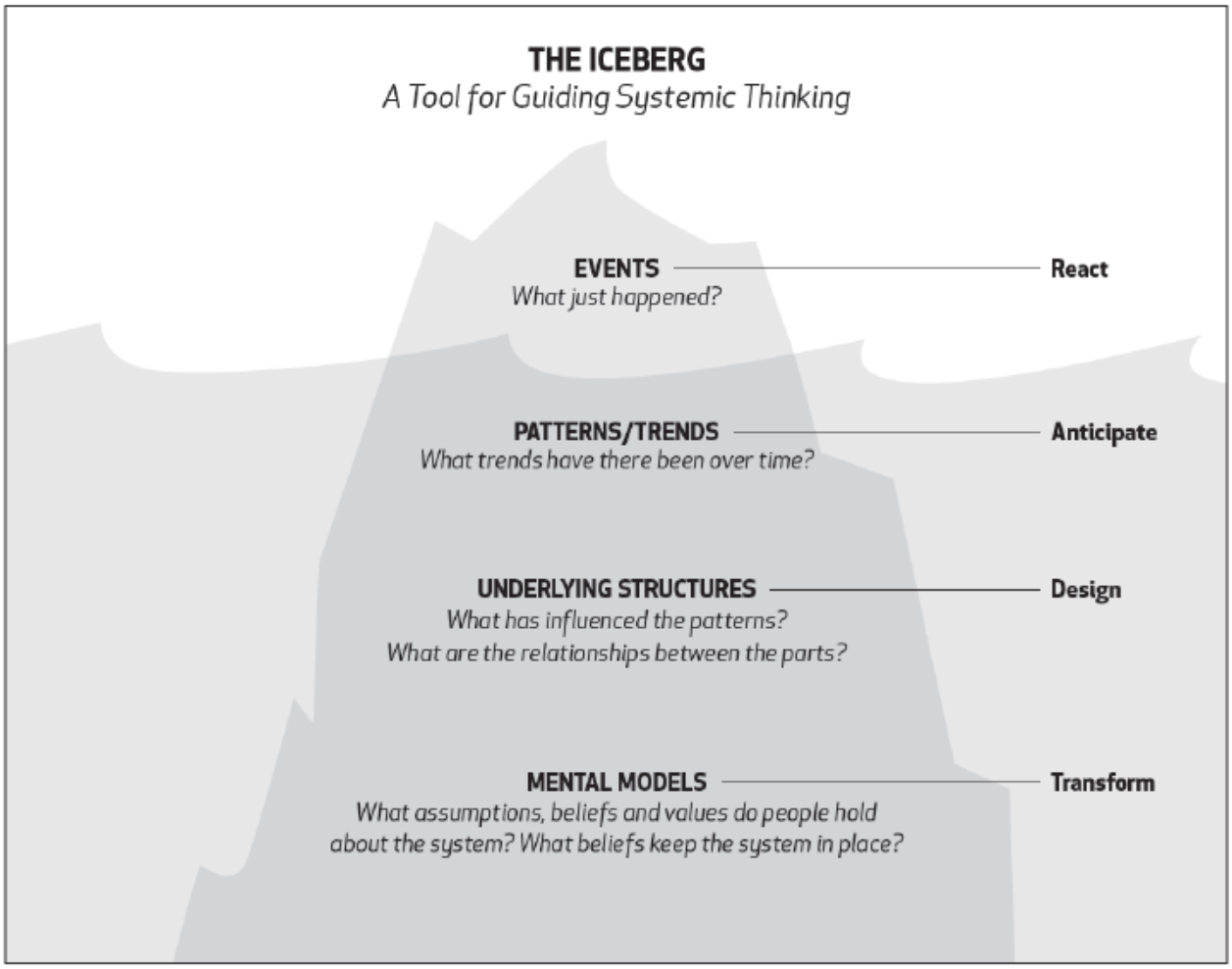


Figure 1. Understanding System Behavior[2]

[2] Source: Downing et al., 2018 (adapted from the NW Earth Institute)

2. EXISTING FRAMEWORKS AND PRINCIPLES FOR SEED SYSTEM RESILIENCE

A small number of publications offer frameworks, principles or pathways that help in understanding seed system resilience[3]. Some are more conceptual and rooted in the academic and applied literature (e.g., McGuire and Sperling, 2013; Louwaars and Manicad, 2022) whereas one is more action-oriented, based on a combination of research and experiential perspectives from around the world (Global Alliance for the Future of Food, 2019). At a more practical level, the International Seed Federation, which represents the global seed industry, is also applying the concept of 'seed resilience' through a pilot project in Rwanda (Annex 6. International Seed Federation (2023): Seed resilience; ISD, 2023a). Though there are some fundamental points of disagreement over policy-related issues (see below), there is a broad level of consensus conveyed by these different approaches in the elements that contribute towards seed systems resilience, as shown by the summarized extracts provided in **Annexes 1 to 5**. Some of these elements – diversity, connectedness, governance, for example – are key characteristics of the resilience framework described in 3. Proposed framework for seed system resilience. Other elements, such as information, trust, and innovation, are implicitly embedded in the framework, as highlighted in 3.4 Information, trust, and innovation.

2.1 Seed system typologies

With some exceptions (e.g., Subedi and Vernooy, 2019), most authors addressing the topic of seed system resilience recognize the distinction between formal and informal seed systems, though they address this in different ways. Louwaars and Manicad (2022), for example, describe the strengths and vulnerabilities of farmer and formal seed systems respectively and identify options for increasing resilience within each system. The complementarity of the two systems is recognized as a source of resilience, allowing for a greater diversity of crops, varieties, and seed sources, particularly when one system can fill the gaps within the other system, or in a situation where one system can step up in case the other system might falter.

Westengen et al. (2023) highlights the complementarities between farmer and formal seed systems but argue that seed systems should be presented in a more holistic way, based on five factors that are common across any seed system (see **Figure 2**). They structure their analysis according to the activities of different actors involved in seed system functions and illustrate how different partnerships and collaborations between different actors have led to both technical and institutional innovations within seed systems. The breeding and release of new varieties by plant breeders, for example, can be seen to benefit the farmer seed system by making new varieties available to farmers. On the other hand, they also recognize that the activities of different seed systems actors have the potential to cause harm to farmer seed systems. An example of this is the formal seed policies and laws that exist in some countries that effectively outlaw customary practices such as farmer seed-saving and exchange[4]. To promote resilient and inclusive seed systems, Westengen et al. propose the principle of 'Do No Harm', so that development does not result in harm to the farmer seed system.

[3] Key publications (in chronological order) include McGuire and Sperling (2013); Subedi and Vernooy (2019); Global Alliance for the Future of Food (2019); Louwaars and Manicad (2022); and Westengen et al (2023).

[4] Although there is no evidence of such laws being implemented in practice, it is perhaps reflective of the attitudes and perceptions that policymakers and some technical experts have of informal seed systems in relation to formal seed systems and the biases that exist.

Figure 2. Conceptual framework with key functions and contexts for seed system development[5]

The holistic view of seed systems is taken further by the Global Alliance for the Future of Food (2019) who propose a paradigm shift to allow for multiple visions and ways of understanding seed systems. They highlight the on-going and dynamic role of smallholder farmers and Indigenous Peoples in managing seed diversity and want to see the recognition of different scientific practices and knowledge exchange based on transdisciplinary, cross-scalar, and participatory approaches. They advocate for a transition from industrial food systems and chemical intensive agriculture to agroecology and economically viable and culturally appropriate food and agricultural systems that promote health, well-being, and ecosystem services. They also promote a rights-based approach that strengthens farmers' rights within local and international policy environments and recognizes local control, equity, and social justice.

2.2 Power, equity, and policy perspectives

Where the existing frameworks and principles differ is in the extent to which they consider issues relating to power and equity. Louwaars and Manicad (2022) make no mention of these issues, and McGuire and Sperling (2013) refer briefly to farmer empowerment in relation to access to knowledge and information. Subedi and Vernooy (2019) consider the empowerment of farmers to be a core element of a comprehensive resilience strategy and emphasize the importance of making farmers' voices heard in national and international decision-making processes that relate to the management of plant genetic resources, seed system development, agricultural production, and livelihoods. None of the frameworks explicitly consider power and equity in relation to differences among farmers according to ethnicity, economic class, sex, age, etc.

All three of the principles laid out by Westengen et al. (2023) either implicitly or explicitly touch on aspects of power and equity by highlighting: (i) the negative spill-over effects of seed policies and laws on farmers' seed systems; (ii) the diversity bottlenecks that can be caused by power concentrations at different levels and the need for multistakeholder platforms with diverse representation; and (iii) the call for the concept of 'agency' to be incorporated into the seed security framework to help address power, governance and equity within seed systems (Clapp et al., 2021).

Issues of power and equity are placed front and center within the principles presented by the Global Alliance for the Future of Food (2019). They state that 'Resilient seed systems… require advocating for economic and social rights, the right to nutritious, culturally appropriate food of sufficient quality and quantity, and environmental justice…. Indigenous Peoples and smallholder farmers must be actively involved in decision-

[5] Source: Westengen et al., 2023

making'. Like Westengen et al., members of the Global Alliance are concerned that current seed laws and policies are undermining farmer seed systems (Global Alliance for the Future of Food, 2016), and – among various other enabling policies – they want to address the oligopolies and concentrations of power within the seed system, suspend Intellectual Property Rights laws, and redesign seed policies to exclude the patenting of plants and parts of plants.

In contrast, Louwaars and Manicad (2022) highlight the importance of long-term investment for plant breeding and argue that plant breeder's rights are necessary in securing the income needed for private sector breeding. They also state that farmers themselves must continue to adapt and innovate within their changing context, and that breeders must work closely with farmers to ensure that farmers' needs are met, including the use of participatory diagnostics.

These differing perspectives relating to power and equity partly stem from long-standing debates within the seed systems discourse in which there has been a tendency for contributors to champion either the formal seed system or the informal seed system, unhelpfully (and often unintentionally) pitting the agendas of agricultural modernization against those of food sovereignty (Westengen et al, 2023; Scoones and Thompson, 2011). They also partly stem from literature within the food systems discourse that highlight concerns about the effects of growing corporate concentration within the global food system (Clapp, 2021; Howard, 2016). At a global level, for example, the seed and agro-chemical industry is currently dominated by just four large firms (Bayer, Corteva, Chem China-Syngenta and BASF) after three major mergers took place between 2015 and 2018.[6] These companies exert power both directly and indirectly by shaping not only seed markets and the crop varieties that are grown, but also technology and innovation agendas, and policy and governance frameworks (Clapp, 2021).

2.3 Seed system resilience and seed security

According to the FAO, seed security 'exists when men and women within the household have sufficient access to quantities of available good quality seed and planting materials of preferred crop varieties at all times in both good and bad cropping seasons' (FAO, 2016: 6). Seed security is commonly understood according to four parameters[7]: (i) seed availability; (ii) seed access; (iii) seed quality; and (iv) varietal quality/appropriateness and is generally defined at the level of an individual male of female farmers or a household. Not only does seed security vary among different farmers (generally corresponding to their relative socio-economic status), but it also varies for different crops and different seasons.

In contrast, seed system resilience encompasses both formal and informal seed systems and all the actors within the value chains for different crop and seed classes. As described above, changes within a system take place at different levels and over different time periods. As such, seed system resilience is more expansive, enduring, and complex than seed security.

[6] Bayer purchased Monsanto in 2018; Corteva was formed after the merger of Dow and DuPont in 2015; and ChemChina-Syngenta was formed in 2016 when ChemChina purchased Syngenta (Clapp, 2021).

[7] Westengen et al. (2023) support the addition of two more parameters, sustainability and agency. They argue that sustainability is required to emphasize the need for seed systems to maintain the biological basis for long-term functioning, and that agency allows for an awareness of how power is distributed in the system. In the framework presented here, sustainability and agency are considered at the level of seed system resilience, not at the level of seed security.

3. PROPOSED FRAMEWORK FOR SEED SYSTEM RESILIENCE

3.1 Defining seed system resilience

Seed system resilience is understood as the ability of a seed system to maintain functionality and to withstand, adapt, and recover from the effects of shocks and stressors in a manner that, ideally, helps to reduce chronic vulnerability and facilitate inclusive growth. As illustrated above, the three key functions of a seed system are: (i) variety development and management; (ii) seed production; and (iii) seed dissemination (**Figure 2**). The types of shocks or stressors that might negatively affect seed systems include both long-term trends or stressors and short-term shocks. The impact of these shocks and/or stressors is also determined by the level of exposure in terms of their severity, frequency, and duration (**Figure 3**). Long-term trends or stressors include climate change, environmental degradation, social inequities, chronic conflict or insecurity, and market/economic crises. Shocks include both slow-onset shocks such as drought, pandemics, or crop pests and diseases, as well as rapid-onset shocks such as floods, cyclones, and conflict. The distinction between long-term trends and short-term shocks might become blurred in some cases, e.g., recurring drought or new conflicts that become prolonged.

The level of resilience of a seed system determines whether it has the capacity to absorb, adapt, and/or transform in the face of shocks or stressors (**Figure 3**). A seed system which lacks resilience is unable to absorb, adapt or transform and leads to varying levels of seed insecurity for some crops and for some farmers. The outcome of seed system resilience is defined here as functional and inclusive seed systems that enhance seed security for male and female farmers and contribute to improved food, nutrition, and livelihood security, as well as healthy and sustainable ecosystems. Resilient seed systems ultimately provide inclusive benefits to farmers and other seed system actors, whether individuals, households, communities and/or businesses.

Following the market systems resilience framework, and drawing on the seed systems literature, this paper distinguishes six characteristics that contribute to seed systems resilience, three of which are structural and three are behavioral, as described below.

3.2 Structural characteristics of seed system resilience

Diversity refers not only to the range of crops, varieties and seed classes[8], but also to the diversity of farmers within and between communities, the diversity of seed sources (e.g., other farmers, traders, agro-input dealers, seed companies, non-governmental organizations [NGOs], or government projects) and the mechanisms through which farmers can access seed (e.g. own-production, exchange, gift, purchase, loan, voucher), the diversity of seed storage mechanisms. The diversity of and agro-ecologies and the diversity of crop/varietal uses (e.g., whether for human consumption, for livestock consumption, for processing, for sale) both act as drivers for crop and varietal diversity. Within the private seed sector, diversity includes the different companies and businesses of different sizes researching, breeding, producing, supplying, marketing, and distributing different seed classes (e.g., early generation seed [EGS], certified seed, standard seed) of a range of crops and varieties. In the public sector there is also a range of government and international organizations as well as universities involved in researching, breeding, producing, supplying, and distributing different seed classes.

[8] The term seed class is used here to refer to whether it is certified seed from the formal seed sector, Quality declared seed (QDS), farmer seed, or what is often referred to as 'potential seed', i.e., seed that is sourced from local grain markets. EGS is another seed class, used specifically for seed multiplication in formal and intermediate seed systems.

Connectivity is 'defined by the way and degree to which actors, resources, or species interact across geographic, ecological, and social landscapes' (Downing et al., 2018). Seed-based interactions among farmers are commonly facilitated through well-established social networks, both within and between communities, sometimes over considerable distances. It is important to note that different farmers within the same community will have different social networks and varying levels of access to these networks, according to gender, age, ethnicity, socio-economic class, and even their individual personality traits (e.g., extrovert, introvert, etc.). Some individuals might be excluded from some networks for various reasons. It is also common for markets and traders to play an intermediary role in allowing for the sale or exchange of seed among farmers. Linkages between formal and informal seed systems allow for plant breeders to access genetic material in the form of landraces or farmer varieties for use in plant breeding and selection, and farmers can acquire seed of improved varieties through their connections with NGO or government projects, agro-input dealers or seed companies. These connections will vary for different farmers according to certain demographics such as sex, age, and relative wealth, depending on the inherent biases and/or targeting criteria of projects and marketing strategies. Information about different varieties and how they can be acquired is crucial to these connections.

Just governance and power dynamics refer to the level of equity, fairness and inclusiveness inherent in the formal and informal rules and norms that govern seed systems, as well as the relative concentration and exercise of power within a system (Box 1). At the global level, such governance mechanisms include international biodiversity agreements and intellectual property rights. At the national level, formal policies, laws and regulatory systems exist to govern the release of varieties, to control for seed quality, to register formal sector seed actors, and to designate the entities authorized to perform these various functions. At the local level, there are customary laws, social norms, principles and beliefs that influence farmers' practices in seed saving, exchange and use (Westengen et al., 2023). The notion of inclusivity in relation to just governance refers not only to gender, age and ability, but also to the recognition of and unbiased support to all seed sub-systems, i.e., formal, intermediate and informal seed systems (Africa Seed, 2023; Westengen et al., 2023).

As noted above, some authors have highlighted the comparative power of the formal seed system, such that national seed policies may disadvantage the informal seed system. At a national level, power dynamics might refer to the relationship between the government and the private sector and the ways in which power is exercised, or the power dynamics among different seed companies. At the international level, the concentration of power within a relatively small number of large seed companies is a cause for concern because they can potentially use their power to influence seed markets, technology and innovation agendas, as well as both national and international governance frameworks (Clapp, 2021).

Box 1. Power dynamics, governance, and social justice

Power dynamics are defined as the relative concentration and exercise of power in a system. Too much concentration of power can limit access to resources, while too little concentration of power can result in an inability to reach consensus on key decisions. How power is exercised in a system is intertwined with bias, such as when one group is favored over another for political advantage. How power is exercised often aligns across a continuum from a system orientation that reinforces a concentration of power for the benefit of the few at one end to a system that reinforces diversity of power for broader and more inclusive social benefit. In market systems, typically when power is overly concentrated, the result is monopolistic or oligopolistic structures that support extractive and practices behaviors. These practices, in turn, lead to concentrations of wealth that are dependent on exclusion rather than inclusion. Such structures tend to be rigid, inflexible, and fragile — making them less resilient in the face of shocks and stresses compared to those where power and wealth are more broadly shared, and solutions and resources to address shocks are more diverse.

Whether in market or political systems, the concentration of power influences the rule of law. The concentration of power by itself is not necessarily a problem and is, in fact, typically the norm. However, when there is increased concentration of power around a single identity group, there is less capacity in the system to push back when that group wields power in ways that only favor its own members. This is why monopolies and oligopolies, over time, tend to use their power to ensure their position, and limit others from gaining market power by bending the rule of law in their own favor. Systemic change is often most effective when nodes of power are wielded in ways that push against deep-seated biases.

Extracted from Downing et al. (2018: pp 9-10)

3.3 Behavioral characteristics of seed system resilience

The following three behavioral characteristics determine how seed system actors – whether individuals, businesses, private companies, or organizations – respond to different stimuli and the resulting behavior patterns (Downing et al., 2018). The behaviors mentioned below are applicable to actors in both the informal and formal seed systems, including small-scale businesses (e.g., an individual informal trader or a farmer seed-producing group or a formal, registered agro-dealer) and larger-scale businesses or companies. As described below, these characteristics are strongly influenced by access to information, and the underlying motivations, principles and beliefs of individuals and businesses and their broader communities or cultures.

Decision-making takes place at various levels and by a range of actors. For example, individual farmers or farming households must decide which crop varieties to plant and how to acquire the seed; agro-input dealers must decide which seeds to stock and how to market them; NGO actors supporting seed system development or providing humanitarian assistance in response to emergencies must decide how to design their interventions, the focal crop and seed classes, and the programming modalities[9] to be used. Within the private seed sector, large seed companies must decide on the range of crops and varieties to produce, in what quantities and at what price, and whether to invest in crop breeding and what kinds of varieties should be developed if so. What is key in all these decision-making processes is the extent to which the decision-makers have access to the information required for well-informed decisions, how much agency or power the entity has in making the decision, and to what extent these decisions are made in the interests of farmers (as the end-users of seed).

Cooperation / competition refers to seed system actors collaborating to achieve a common purpose or competing as rivals. Cooperation and competition themselves are neither good nor bad, but it is the motivation behind them that can either strengthen or weaken the resilience of a system (Downing et al.,

[9] Within emergency seed security interventions, programming modalities typically refer to whether seed is provided through direct distribution, through voucher-based assistance, or through cash transfers.

2018). For example, cooperation among system actors for the purpose of collusion (e.g., price-fixing, or to produce 'fake seed') has negative consequences for resilience, whereas cooperation that adds value to system performance helps to build resilience by strengthened performance and risk-sharing among collaborators (ibid.). Competition between seed companies (e.g., between multinationals and domestic companies), or between public and private entities, or between formal and informal seed system actors, for example, can lead to the creation of exclusionary policies, or processes that favor one system over the other. On the other hand, competition based on the value of seed and services delivered to customers can lead to enhanced seed and varietal quality, improved production and distribution efficiency, reduced seed costs, and enhanced information flows.

Cooperation to add value to seed system resilience can occur in various ways and at different levels. Cooperation between different farmer types (e.g., refugees and host communities) can help to ensure timely access to seed of appropriate varieties. Farmers might form a group or cooperative and work together to multiply seed of improved varieties. Cooperation between different actors from the formal and informal systems ensures that intermediate seed systems function in the ways they are intended, e.g., for the supply of EGS for farmer seed production; for participatory plant breeding/selection. Seed system actors might form associations (e.g., seed traders associations or national farmers associations) to advocate for a change in policies to create greater equity, e.g., seed certification classes that enhance farmers' access to quality seed; reduction in importation tariffs of agricultural equipment to reduce the costs of seed production.

Business strategy refers to the general orientation of a business that tends to favor one of two objectives: (i) maximizing margin capture through 'zero-sum' transactions in which competitors and/or customers lose out; or (ii) generating value for customers as a strategy for increasing growth (Downing et al, 2018). Examples of zero-sum transactions might include selling fake or adulterated seed, manipulation of weights and measures, or mis-informing customers. Examples of transactions that generate value for customers include investments to better understand customer needs, building customer relationships, tracking customer retention and growth, investing in staff and business capacity, and merit-based hiring (ibid.). Business strategies that create value for customers generate resilience within seed systems because businesses have good relationships with their customers, and staff are more capable of solving problems; they are thus better able to determine and respond to customer needs in the event of a shock or stress.

3.4 Information, trust, and innovation

Other seed systems resilience frameworks and the broader seed systems literature highlight additional aspects that are central to resilience – these include knowledge and/or information, trust, and innovation. The role of knowledge and information has been mentioned above in relation to connectivity, e.g., knowing who to contact and how to find them to access seed of a particular variety (as well as knowing about the variety itself). Knowledge and information are also essential for informed decision-making by all actors. The sharing of knowledge and the flow of information can either be enhanced or constrained by behaviors such as cooperation and competition, as well as business strategy. Two-way flows of knowledge and information are essential for effective cooperation, collaboration, and innovation.

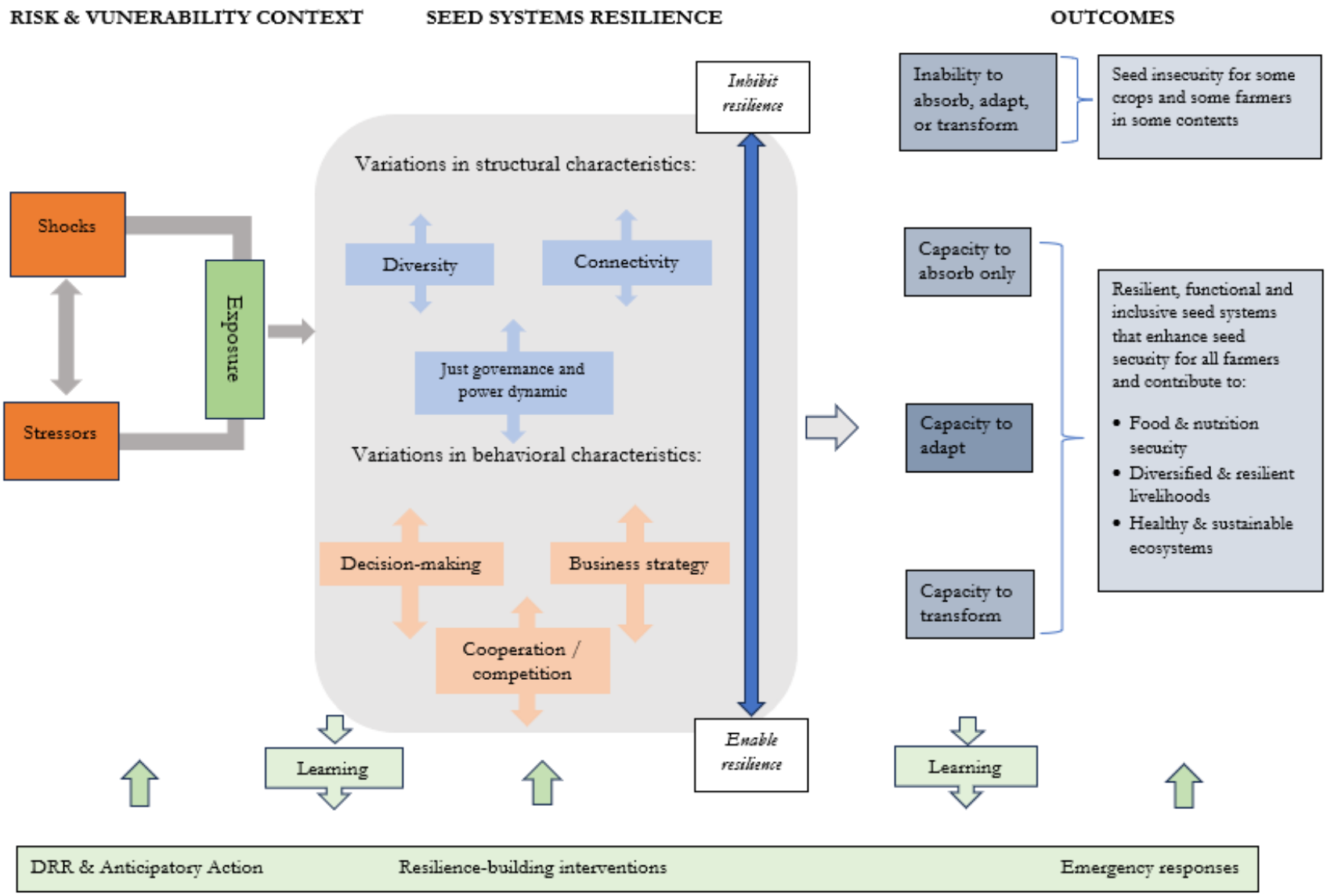
Trust is both generated through certain behaviors and a necessary component of them. For example, cooperation between actors (e.g., a farmer and a crop researcher) requires a certain level of trust to begin with and is also strengthened or reinforced by a positive working relationship or through cooperation over time. Similarly, a business that aims to generate value for customers will behave in a manner that generates trust on the part of its customers so that those customers will continue to patronize the business. When acquiring seed, for example, farmers determine seed quality not only according to a visual assessment of the seed itself

but also according to their level of trust in the seed provider.[10] If a farmer has had a good experience in acquiring seed from a specific provider (whether another farmer, an informal trader or a formal agro-input business), then they will be more likely to trust that person or business to provide good quality seed again in future.

Innovation is essential if seed systems are to be able to adapt to and recover from the effects of stresses and shocks. Innovation might include new crop varieties or other technologies developed by farmers and/or researchers; new partnerships, new institutional arrangements, or new ways of working together among seed system actors; novel ways of sharing and managing knowledge and information; new business models or financing mechanisms; new policies or regulatory controls; or new types of external interventions, to name just a few. Innovative partnerships or ways of working together can themselves lead to technical innovations.

[10] This is especially important in assessing quality traits that cannot be determined merely by visual inspection, e.g. germination, genetic vigor, genetic purity, as well as the characteristics of the variety itself, such as drought tolerance, yield, taste, etc.

Figure 3. A Framework for Seed System Resilience



4. TYPES OF INTERVENTIONS THAT CAN POTENTIALLY BUILD RESILIENCE INTO SEED SYSTEMS

The diagram in **Figure 3** indicates three different categories of interventions: (i) those intended to reduce the negative effects of trends, shocks and stressors, e.g., disaster risk reduction and anticipatory action; (ii) those intended to build resilience; and (iii) seed security interventions implemented in response to a disaster. Although this categorization appears to imply a sequencing of interventions pre- and post-disaster, resilience-building interventions are defined more by their overall aims and objectives and can be designed to be implemented in either emergency or developmental contexts. Interventions that aim to enhance seed system resilience are particularly important in risk-prone environments and protracted crisis settings. Ideally, emergency interventions should also strengthen rather than undermine seed system resilience.

Table 1, below, presents various suggestions for different types of interventions that can support seed system resilience, structured according to the eight characteristics described above and the key seed system functions and contexts, as presented in **Figure 2**. Many of the interventions require long-term approaches, particularly those that support Variety development & management, Seed governance and Food system drivers. However, many can also be implemented alongside emergency projects, particularly those relating to seed production & storage and seed dissemination & access, as illustrated by the grey-shaded cells in **Table 1**. Some of these simply require appropriate messaging, information, and awareness raising (e.g., to promote crop and varietal diversification), others require market linkages and/or capacity development at different levels, some of which can be implemented alongside market-based approaches such as vouchers.

The table is intended to provide a more structured way of thinking about interventions that can potentially build seed system resilience. Potential interventions are presented as overall aims or objectives, with the expectation that implementing organizations, development practitioners, and policymakers can use these to help design specific activities, interventions and policies that fit within the broader aims.

Table 1. Possible intervention options to promote seed system resilience

Shaded cells indicate actions that are possible as part of emergency interventions

	Variety development & management	Seed production & storage	Seed dissemination & seed access	Seed governance	Food system drivers
Diversity	• Promote awareness at all levels about value of crop and varietal diversity • Support to crop research & breeding by diverse range of organizations for diverse crops & varieties	• Promote farmer awareness about importance of seed-saving, esp. for local varieties / landraces • Enhance and diversify farmer and trader seed storage practices where necessary • Encourage crop and varietal diversification by a diverse range of seed producers	• Encourage crop and varietal diversification by a diverse range of seed suppliers (informal traders, NGOs, agro-dealers, etc.) • Support to a diverse range of 'last-mile' seed providers and models	• Ensure that formal seed laws recognize and allow for production, trade and exchange of multiple seed classes (e.g., farmer seed, QDS, standard seed, certified seed, EGS, etc.) by a diverse range of seed producer types • Ensure that formal seed laws recognize and allow for the production, trade and exchange of local varieties and landraces	Promote demand-centered rather than supply-centered seed system development that recognizes the value of crop and varietal diversity
Connectivity	• Encourage linkages and collaboration between male and female farmers and plant breeders • Ensure that plant breeders have access to a diverse range of appropriate genetic material for breeding and selection purposes	• Strengthen linkages between EGS suppliers and different seed producer types • Promote market linkages between farmers, traders and input suppliers for effective seed storage solutions	• Encourage social cohesion among / between different farmers to allow for seed / varietal exchanges • Promote market linkages between different farmers and different seed providers (e.g., informal traders, NGOs, agro-dealers, seed enterprises, etc.)	• Ensure that formal seed laws recognize and encourage interactions between formal, intermediate and informal seed systems	• Promote demand-centered rather than supply-centered seed system development in which diverse food preferences are catered for by diverse seed system solutions
Just governance and power dynamics	• Promote equity, fairness and inclusiveness in formal	• Promote equity, fairness and inclusiveness in formal	• Promote equity, fairness and inclusiveness in formal	• Promote equity, fairness and inclusiveness in	• Promote equity, fairness and inclusiveness in formal

	Variety development & management	Seed production & storage	Seed dissemination & seed access	Seed governance	Food system drivers
	rules, customary laws, social norms and beliefs that influence the management and use of crop genetic diversity by all actors • Ensure that interventions do not inadvertently disadvantage informal or intermediate seed system actors or varieties	rules, customary laws, social norms and beliefs that influence the production and storage of all seed classes by all actors • Ensure that interventions do not inadvertently disadvantage informal or intermediate seed system actors, varieties or technologies	rules, customary laws, social norms and beliefs that influence seed access and dissemination of all seed classes by all actors • Ensure that interventions do not inadvertently disadvantage informal or intermediate seed system actors, varieties, or channels of seed acquisition •	formal rules, customary laws, social norms and beliefs that influence the management and use of all seed classes and crop genetic diversity by all actors • Ensure that formal seed policies do not disadvantage informal or intermediate seed systems • Promote more effective national and international regulation of corporate power concentration	rules, customary laws, social norms and beliefs that influence food and seed systems • Promote inclusive and demand-centered rather than supply-centered seed system development which avoids harmful power concentrations •
Decision-making	• Ensure that farmers, crops scientists and others have access to the information needed to support well-informed decisions relating to variety management and development, that are made in the interests of farmers. • Use participatory and inclusive practices to hear from those less heard	• Ensure that seed producers and others have access to the information needed to support well-informed decisions relating to seed production and storage, that are made in the interests of farmers. • Use participatory and inclusive practices to hear from those less heard	• Ensure that seed providers and others have access to the information needed to support well-informed decisions relating to seed dissemination and seed access, that are made in the interests of farmers. • Use participatory and inclusive practices to hear from those less heard	• Ensure that leaders, seed system actors, technical advisers, policymakers and others have access to the information needed to support well-informed decisions relating to seed system governance, that are made in the interests of farmers. • Use participatory and inclusive practices to hear from those less heard	• Ensure that leaders, technical advisers, policymakers and others have access to the information needed to support well-informed decisions relating to food and seed systems development, that are made in the interests of consumers and farmers. • Use participatory and inclusive practices to hear from those less heard
Cooperation / Competition	• Support cooperation and healthy	• Support cooperation and healthy	• Support cooperation and healthy	• Support cooperation and healthy	• Support cooperation and healthy

	Variety development & management	Seed production & storage	Seed dissemination & seed access	Seed governance	Food system drivers
	competition among male and female farmers, crop scientists and others for variety development and management approaches that enhance seed system equity and resilience	competition among seed producers and others for seed production and storage approaches that enhance seed system equity and resilience	competition among seed providers and others for seed dissemination and seed access approaches that enhance seed system equity and resilience	competition among seed system actors, policymakers and others for seed system governance approaches that enhance seed system equity and resilience	competition among food and seed system actors, policymakers and others for developments that enhance seed system equity and resilience
Business strategy	• Support the capacities of farmers, crop scientists and others to develop varieties and management strategies that meet the needs of male and female farmers in response to changing conditions	• Support the capacities of different seed producers to generate value for their customers and to be better able to respond to customer needs in the event of a shock or stress	• Support the capacities of different seed providers to generate value for their customers, reduce barriers in accessing seed, and to be better able to respond to customer needs in the event of a shock or stress	• Support the capacities of seed system actors, policymakers and others for seed system governance strategies that meet the needs of male and female farmers in response to changing conditions	• Support the capacities of food and seed system actors, policymakers and others for developments that meet the needs of male and female farmers in response to changing conditions

5. CLOSING REMARKS

Seed system resilience is important not only in relation to the effects of climate change on agricultural systems but also due to the increasingly protracted nature of emergencies. Conventional seed interventions in emergency contexts are intended to provide farmers with seed or access to seed for the next planting season so that they can produce sufficient food to meet their needs. As such, emergency seed interventions are driven largely by the need for food security, with relatively little understanding of the impacts of such interventions on broader seed systems. Emergency seed interventions that are repeated over multiple years in protracted crisis situations have been seen to have unintended negative consequences on seed markets and on longer-term efforts to promote seed system development (Longley, 2023; Longley et al., 2023). It is thought that interventions that are designed to enhance seed system resilience will have more positive impacts on seed systems and hence also more long-lasting positive impacts on food security. As such, a seed systems resilience approach is thought to be more appropriate than conventional approaches to emergency seed interventions in protracted crises. Considerably more evidence than currently exists will be needed to be able to determine the actual impacts of such interventions.

Alternative approaches to strengthening seed security in protracted crises are also needed due to the expanding levels of need in relation to the comparatively lower increase in the levels of funding for emergency responses. From 2015 to 2023, for example, the number of people in need rose from 78 million to 362 million (representing an increase of 364%), whereas the global humanitarian aid requirements grew just 184% in the same period (from $19.5B to $55B) (UN-OCHA, 2023). The food security sector is the biggest sectoral driver for this increase in need. There will be a cliff fall in the level of funding available for 2024 due to reduced aid budgets announced by key donors, indicating the urgency in finding alternative ways to support seed security that do not rely solely on humanitarian aid budgets (ibid.). In this respect, the advantage of resilience-building approaches is that they can be funded through either humanitarian or development aid budgets.

The seed system resilience framework presented here offers a more structured conceptualization of seed system resilience and the types of seed-related support that are appropriate in the face of climate change and in protracted crisis contexts. In contrast to earlier frameworks (which have tended to focus solely on the structural aspects of seed system resilience), the framework presented here highlights the behavioral aspects of resilience. The human element within seed systems cannot be ignored. Seed system changes are influenced by the behaviors and choices that are made by seed system actors, which in turn are influenced by their underlying motivations, values, and biases. This can be illustrated by the example of formal and informal seed systems. It is widely agreed that seed system resilience requires linkages between the formal and informal seed systems. At a structural level, this relates to the characteristics of diversity and connectivity. However, for meaningful interactions between these systems, it is necessary for the actors themselves to choose to cooperate and work together at certain levels. Effective cooperation requires information, effective communication, understanding and trust between the actors concerned. Although the rationale and advantages of such interaction might be obvious to all concerned, as humans – especially those with different perspectives, backgrounds, and education levels – effective cooperation is by no means easy. By recognizing the behaviors that contribute towards systems-level resilience, it is then perhaps possible to find ways of addressing or overcoming the human-related challenges.

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ANNEX 1. MCGUIRE AND SPERLING (2013): PRINCIPLES AND PRACTICAL RECOMMENDATIONS FOR SEED SYSTEM RESILIENCE

Based on eight key principles from the socio-ecological systems literature, McGuire and Sperling define resilience in seed systems as follows:

> *Resilient seed systems have the capacity to absorb shocks and stress and reorganize so as to maintain and strengthen seed security over time. Resilience emerges as a property of germplasm, institutions, and interactive information systems, which allow for strategic response to change.*

The key principles include:

1. The priority importance of a **systems perspective**, with attention to institutions, relationships, and knowledge, spanning processes in both formal and informal systems.
2. In reference to systems' capacity to absorb shocks and undergo change, maintaining a particular system state (such as a crop profile) should not be the goal, but rather **retaining seed system function**, with maintaining farming livelihoods and alleviating poverty being priority functions.
3. **Diversity** is important for seed system resilience, in terms of crop, of variety and even of supply channels.
4. **Temporal breadth** needs to be integral; shaping resilient seed systems also requires longer-term strategy.
5. **Innovation and learning** are also central for responding to dynamic change; this means that technology provision should be linked to relevant information to assist strategic decision-making.
6. Related to learning is that **feedback loops** must be fostered among different parts of systems, for instance, between farmer–clients and suppliers, or between traders and formal institutions.
7. Change must be managed in a way that strikes a balance between sustaining and transforming systems. For seed systems, this suggests a **repertoire of flexible responses**, which help smallholder farmers to maintain current seed security features (availability, access, utilization), but which also enable them to transform and evolve.
8. Finally, the resilience literature cautions that **trade-offs** are a risk in managing for resilience. Interventions must consider trade-offs between multiple stresses and risks.

The authors go on to elaborate five overarching thrusts that can help enhance seed system resilience:

i. **identifying germplasm** suited to different scenarios, which can be re-vitalized quickly: 'crop/seed systems in reserve'.
ii. **enhancing availability** of this germplasm: broadening initial formal and informal seed supplies and multiplication possibilities;
iii. **securing access** to diverse seed particularly through the use of multiple channels (including through local markets); and planning especially to encourage access by more vulnerable groups;
iv. **fostering information systems** that strengthen capacity for tailored response at varied levels (including at farmers') and which promote continued learning; and
v. **enabling evolution of systems to capture new repertoires and opportunities**. Linking seed systems to dynamic elements, particularly those opening commercial opportunities (new markets, transformation) or those which might cross geographic boundaries.

ANNEX 2. SUBEDI AND VERNOOY (2019): PATHWAYS TO RESILIENCE

Subedi and Vernooy's definition of a resilient seed system is one which:

- Relies on the ability of seed system actors to absorb disturbances, **regroup or reorganize**, and adapt to stresses and changes caused by a perturbation
- Results from multiple seed and knowledge interactions and **continuous learning** among seed system actors and related institutions
- Is **demand driven and responsive** to differentiated needs and interests supporting all users and farming systems
- Recognizes, respects and supports the key roles played by **women farmers** as seed custodians, managers, networkers, and entrepreneurs.

Resilient seed systems reduce vulnerability by:

- Ensuring **seed security** (access, availability, quality)
- Guaranteeing seed **choice and diversity**
- Producing crops which underpin a **healthy diet**
- Recognizing and respecting seed as **social and spiritual capital**

Ultimately, farmers should benefit from a secure and diversified supply of quality seeds suitable for local conditions and which contribute to healthier diets, more sustainable livelihoods and stronger capacity to adapt to climate change. Useful and timely **information** should accompany seeds, for example, regarding the nutritional value of the variety, capacity to withstand drought, and recommended management practices.

Core elements of a comprehensive resilience strategy are:

- Smarter ways of addressing climate change
- Identifying best-bet portfolios
- Novel and efficient distribution
- Innovative business models and value chains
- Empowerment of farmers
- Local implementation of international and national policy

ANNEX 3. GLOBAL ALLIANCE FOR THE FUTURE OF FOOD (2019): PRINCIPLES FOR RESILIENT SEED SYSTEMS

The following principles were proposed by participants of a strategic convening on resilient seed systems in 2018 in Oaxaca, Mexico. They are adapted from the Global Alliance principles for sustainable food systems.

DIVERSE: Resilient seed systems are rooted in communities that have diverse systems of knowledge, cultures, ecologies, economies, and societies. These communities use agroecological approaches to steward, manage, protect, and defend seed diversity.

COMPLEX AND DYNAMIC: Resilient seed systems prioritize the exchange of diversity within and between agroecological systems because it improves the capacity for humans and natural systems to adapt or transform when faced with shocks and stresses such as hurricanes, droughts, pest outbreaks, market volatility, and political unrest.

EQUITABLE AND RIGHTS-BASED: Resilient seed systems address issues of power and equity, and require advocating for economic and social rights, the right to nutritious, culturally appropriate food of sufficient quality and quantity, and environmental justice. The knowledge and practices of smallholder farmers, especially women and Indigenous Peoples, play an essential role in the dynamic management of agricultural biodiversity. Indigenous Peoples and smallholder farmers must be actively involved in decision-making.

RENEWABLE: Resilient seed systems have the capacity to renew, replicate, multiply, and evolve to ensure a healthy planet today and for future generations, which is particularly important as we face the challenges of a changing climate.

HEALTHY: Resilient seed systems provide cultural and biological diversity — the basis for improved dietary diversity and nutrition that is culturally appropriate and can advance the health and well-being of people, animals, the environment, and the societies that depend on all three.

INTERDEPENDENT: Resilient seeds systems depend on networks, linkages, and interdependence within communities, territories, institutions, and others. These networks offer a space to collectively construct resilient and sustainable food systems through knowledge and seed exchange, and movement building where the common good is prioritized.

INTERGENERATIONAL: Resilient seed systems depend on a flow of cultural and ecological knowledge between generations, within households, and across communities. Intergenerational exchange and youth participation are central to resilient seed systems. The role of elders and youth in seed systems should be encouraged and celebrated.

ANNEX 4. LOUWAARS AND MANICAD (2022): OPTIONS FOR INCREASING SEED SYSTEM RESILIENCE

The resilience and vulnerabilities of both the formal and farmers seed systems are dependent on the same three common elements, i.e., (i) the continuous flow and capacity to use a **diversity of plant genetic resources**; (ii) **functioning institutions** pertaining to norms, regulations, systems of exchange and social relation; (iii) **innovation** is crucial for the identification and development of increasingly complex traits needed for plant breeding.

Options for Increasing Farmers' Seed Systems Resilience

- Strengthen the system that enables farmers to continue to adapt and innovate within their changing context.
- Facilitate participatory diagnostics and support farmers' decision making.
- Ensure the farmers' continuing access and sustainable use of a diversity of seeds.
- Strengthen farmers' capacities for seed selection and storage.
- Support farmers to diagnose and manage seed-transmitted plant pests and diseases.

Options for Increasing Formal Seed Systems Resilience

- A basic challenge is economic sustainability of seed production. One solution for supplying more seeds to farmers is through the development of more locally oriented seed enterprises. Different business models and strategies can reach different farmers with different crop seeds.
- Breeding requires a long-term investment and a clear vison of future needs. In private sector breeding, the commercial opportunities provide a basis for such long-term investment. Hence, plant breeder's rights (PBR) are important to secure income, which can guide investments in particular breeding programs.
- Breeding is an interdisciplinary process. Breeders, both in the public and private sector, realize that they cannot operate all by themselves. The breeder needs to be close to scientists, but even closer to the seed producers and farmers who finally determine the value of their work.
- Official quality controls are difficult to sustain. Accreditation is one way to reduce cost, i.e., provide certain tasks to operators in the district or even to the larger seed producers who have the trained human resources under close supervision by the authorities. An advanced form of accreditation is the QDS concept, which may provide solutions to promote seed quality in a lighter supervision regime. In such cases, it is important to avoid undue competition between different kinds of seed suppliers.

ANNEX 5. WESTENGEN ET AL (2023): SOME GENERAL PRINCIPLES FOR RESILIENT AND INCLUSIVE SEED SYSTEMS

Do No Harm: Farmers' seed systems are crucial in the livelihoods of millions of farmers, as well as for long term food system sustainability. Most of the seed farmers use in the Global South are sourced from own harvest or exchanged or traded in social networks or informal markets. While these seed systems are not in and of themselves equally accessible to all farmers, they form the backbone of the seed supply in many countries. The first principle for all seed system development efforts should therefore be to "do no harm" to these systems, but rather to build on them.

Diversity: Farmers need access to a diversity of crop species and varieties and this principle should guide the management and governance of all seed system functions. […] this is not only a question about biological diversity, but also in terms of institutions and actors involved throughout the seed system. A diversity of seed sources is needed to meet the needs of different kinds of farmers in heterogenous food system contexts. It is thus important to maintain and promote diversity of both crops and actors and actively counteract the diversity bottlenecks that can be caused by power concentration at different stages in the system.

Seed Security: The seed security perspective used to assess farmers' access to preferred varieties of seeds in humanitarian contexts should also guide long-term seed system development. The seed system functions analyzed here are processes whose effects can be assessed in terms of seed security outcomes for farmers. The dimensions of seed security correspond to the four commonly recognized dimensions of food security: availability, accessibility, quality, and stability. Recently, two additional dimensions are proposed for food security: sustainability and agency. We suggest that these two new dimensions are also useful additions to the seed security framework, drawing attention to the need for seed systems to maintain the biological basis for long term functioning and the importance of being attentive to how power is distributed in the system.

ANNEX 6. INTERNATIONAL SEED FEDERATION (2023): SEED RESILIENCE[11]

[*Note: although this is not a well-developed framework, the fact that the topic of seed system resilience is being addressed and promoted by the International Seed Federation[12] gives an indication of the growing importance of the term and the need to understand how it is being applied from different perspectives.*]

Seed resilience is defined as 'The adaptability and capacity to contribute to food and nutrition security by making accessible sufficient, diverse, locally adapted, improved, high quality varieties to all farmers, taking into account environment, health and socio-economic aspects'.

Seed resilience needs:

- Continued genetic progress: to produce more on less with less impact on environment, climate, soil (carbon sequestration) and with increased nutritional aspects
- Incentivizing innovation: to encourage, diversify and protect breeding, through science-based, consistent aligned and predictable regulations
- Sustainable seed systems: to create seed choice and access for farmers
- Sustainable seed trade: to increase and diversify seed supply and create seed markets by leveraging experiences
- Functioning markets: to build value chains for farmers

Key points from the ISF pilot project in Rwanda:

In line with key principles of Integrated Seed Sector Development and the vision of the Seeds-for-Food coalition:

- Diversity: different seed systems serve the needs of different farmers
- Interaction: formal and informal seed systems strengthen each other
- Collaboration: variety of public, private, development actors is involved – in line with the Seeds for Food Coalition approach

Experimentation: this pilot project turns the Seeds-for-Food Coalition's vision to practice, is a learning experience, and may be replicated in the future

[11] Although the term used in the presentation was "seed resilience", feedback from members of the panel and the audience highlighted that it is really referring to "seed systems resilience"

[12] The ISF is an international association representing national seed associations and seed companies across 75 countries; it is widely regarded as the voice of the global seed industry.