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Seed exchange networks and food system resilience in the United States

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Abstract:

Seed exchange is a multidimensional issue with social, political, economic and agricultural implications. There is a growing concern about the increase of the food system's vulnerability as a result of loss of agricultural biodiversity. Farmers' ability to replant, exchange, and distribute saved seed is a way to minimize their dependence on commercial suppliers and thereby maintain control over farming practices. Seed saving is also crucial for conservation because the process of choosing, replanting, and exchanging seeds relies on and increases diversity on the farm and in communities. Seed exchange networks, formal and informal ways that farmers engage alongside institutional plant breeding systems, help to conserve agricultural, social, and cultural diversity and identity as well as enhance resilience against environmental and economic shocks. However, how to build resilient seed systems and move from the innovative but relatively isolated project activities of professionals and farmers to a situation where such approaches are scaled up and networked alongside formal and informal, national and international plant breeding mechanism are a concern. This paper examines grassroots seed exchange through seed libraries, the marketing of new varieties through seed companies, and hybrid civil society-business models to understand their financial and technical abilities as well as challenges they face. Seed exchange networks fulfill an important role in conservation of agricultural biodiversity and building community resilience through their work on breeding, exchange, propagation of regionally adapted open-pollinated seeds as well as advocacy on seed sovereignty and education on seed saving.

Keywords: Seed exchange network, seed sovereignty, open-pollinated seed, United States, resilience.

Seed Exchange Networks and Food System Resilience in the United States

> *"It is interesting the variety of names that people have given to their organizations. We have exchanges, banks, companies, foundations and even libraries. I think these are all viable ways of getting seeds in and getting seeds around. The most important thing to me is to keep seeds moving…because then they become part of the fabric of our lives and they mean something. And if they mean something, they'll get grown." Forest Shomer, Abundant Life Seed Foundation, 1981 (quoted in Whealy and Adelman, 1986)*

Introduction

When Hudson Valley Seed Library, a small certified organic farm that breeds and sells heirloom vegetable, flower and herb varieties in upstate New York, decided to breed an indigenous corn, only a few farmers and gardeners still planted the seeds and a handful of restaurant owners were using it for specialty dishes, such as polenta. The indigenous open-pollinated corn, known as Otto File or Eight Row flint corn was available from boutique millers in Italy and only from a few farms and seed suppliers in the United States (NPR 2013a). Flint corn, an open-pollinated corn, used to be a fixture of New England agriculture until the early twentieth century. As one of the fastest maturing varieties and well adapted to the short seasons found at higher altitudes and latitudes above 40 degrees North, where other types of corn fail to ripen, flint corn was cultivated by northeastern Native American tribes (Boutard 2012). The choice of Otto File flint corn as a breeding cultivar for Hudson Valley Seed Library was not a coincidence. Working for seed sovereignty for a decade in northeast United States, Hudson Valley Seed Library collects regional heirlooms and open-pollinated varieties that have been grown within a family or community or region for a period of many generations that grow true when you save seeds from the variety (HVSL 2013). Working with a plant breeding technique that is not hybridization or genetic modification, Hudson Valley Seed Library thus aims to conserve both the genetic material, the seeds, at regional scale and the knowledge for their utilization, communities' cultural stories at the regional scale since conservation of agricultural biodiversity requires both (HVSL 2014; New York Times 2010).

The story of the "near disappearance" of Otto File flint corn is not unique. Farmers in the United States and elsewhere in the world face the loss of seeds that their families and communities have planted for hundreds of years (Nabhan 2008). Indeed, humans have domesticated about 2500 plant species but use only 150 to 200 of them today, and 75% of the world's food is generated from only twelve plants and five animal species (Meyer et al. 2012). Seeds fall into oblivion for multiple reasons, including the industrialization of agriculture and cash crop cultivation, globalization of agribusiness and competition from hybrid and genetically modified seeds (Kloppenburg 2005), homogenization of the global diet, aging and shrinking of farming populations, technological advances, market consolidation (Nazarea 2005; Pautasso et al. 2013) as well as legislative forces that promote commercialization and privatization of seeds (Atalan-Helicke and Mansfield 2012; Kloppenburg 2010). What is unique is the revival of these seeds: Various initiatives work to maintain, improve and make open-pollinating varieties of cereals and vegetables available to farmers and gardeners (Almekinders and Jongerden 2002). Similarly, informal seed exchanges have been formalized as a strategy to address the erosion of agrobiodiversity (Campbell 2012). Amid concerns of food security, farmers' rights and the capacity to develop new varieties that can enhance environmental and economic sustainability, these initiatives aim to address long-term and recent policy and fiscal trends related to plant breeding in science, society, government and food systems (NAPB 2013; Kloppenburg 2013)

Several initiatives by civil society and business have been crucial in the revival of different varieties of flint corn since mid-1990s[1]. In 2005, Stone Barns Center for Food and Agriculture, a multipurpose farm and education center in upstate New York, started growing Otto File flint corn, and chef Dan Barber introduced it in his restaurant (Barber 2014). Hudson Valley Seed Library did several years of field trials and commercially released Otto File in its seed catalogs (New York Times 2010). This paper analyzes the efforts of a multitude of actors instrumental in the revival of open-pollinated vegetable varieties that were once crucial for the livelihoods and food security of Americans and the goals of such actors to bring about an alternative seed production and exchange system in the U.S. As the local plant genetic breeding and exchanges were disrupted in twentieth century U.S., civil society initiatives have emerged, particularly following the passing of the Plant Variety Protection Act in 1970 to support seed sovereignty. Their activities related to seed planting, cultivation, harvest and storage as well as seed exchange alongside an institutional system of management of plant genetic resources aim to take control of plant genetic resources "from the corporations that seek to monopolize them and be restored to, and permanently vested in, social groups and/or institutions with the mandate to sustain them" (Kloppenburg 2010:368). In recent years, there has again been a surge in the seed saving and exchange movement in the United States, such as the emergence of seed libraries, as well as private companies that cater to the diverse variety demands of not only amateur

[1] In 1996, High Mowing Organic Seeds, Wolcott, VT, a private company specializing in providing organic, locally adaptable and non-GE seeds to revive local and sustainable food systems, received the seeds of Roy Calais flint corn from two local farmers who still kept seeds (HMOS 2011). High Mowing Organic Seeds crossed all of the inbred strains, and reintroduced it. Following this initiative, Fedco Seeds, a seed company operating in Clinton, Maine, carried out taste evaluations and added an improved variety of Roy Calais flint corn, Abenaki flint corn, to its seed catalog (Slow Food USA 2015)

gardeners but also commercial organic farmers. While some organic farmers are interested in regionally bred high quality seeds to serve the taste expectations of a clientele at the local or regional scale (HVSL 2013), others point to the discrepancy of conventional seeds to thrive in low-input and organic agriculture systems (van Bueren et al. 2011; Dawson et al. 2008). Organic farming organizations, such as Organic Seed Alliance, acknowledge these needs, and aim to help to formalize organic seed production and distribution activities regionally through partnerships and field trials in California, Southeast and Northwest, and organizing with first-ever California Organic Seed Summit in February 2015 (OSA 2015).

While the initiatives discussed here follow different methods to ensure long-term availability and diversity of seeds to farmers in terms of agronomic and quality traits, they aim to serve both economic and social sustainability and build resilience by connecting farmers and communities with plant scientists, public scientific institutions and seed marketers (Almekinders and Jongerden 2002; Kloppenburg 2010). Plant breeding can be a powerful tool for meeting global environmental challenges by developing "plant products that simultaneously improve food production and the natural environment." (Brummer et al. 2011: 561). The initiatives that address awareness, knowledge and action crucial for motivating communities to assume and take control over their options in biodiversity and natural resource management through access to seeds (e.g. utilization, exchange, propagation), as well as access to plant breeding, also help to build community resilience (Kloppenburg 2010; de Boef et al. 2013) Scholars have discussed how seed exchange networks, formal and informal ways that farmers engage alongside institutional plant breeding systems, help to conserve agricultural, social, cultural diversity and identity as well as enhance resilience against environmental and economic shocks (Campbell 2012; Graddy 2014; McGuire and Sperling 2011). However, building resilient seed systems is a relatively unexplored topic (McGuire and Sperling 2013; Pautasso et al. 2013). The challenge is particularly about how to move from the innovative but relatively isolated project activities of professionals and farmers to a situation where such approaches are scaled up, networked and function on a broader scale alongside formal and informal, national and international plant breeding mechanisms (Almekinders and Jongerden, 2002). Moreover, financial reorganization of the seed sector through mergers and acquisitions which have led to the consolidation of power of a few private companies, declining public investment in classical breeding in particular and funds by the public institutions in general, among other reasons, raise questions about the long-term sustainability of these initiatives (National Research Council 2010).

This paper focuses on initiatives that have some form of institutional structure, scaled up beyond the local scale and collaborated with at least another actor, to explore how each of them organizes seed production and exchange in terms of knowledge, technology and financial terms and how they complement the institutional management system of plant breeding and distribution. Often, these initiatives also engage with direct farmer-to-farmer seed exchange mechanisms at different scales, which have been resilient through the social, political, economic and technological changes in the United States and in different parts of the world[2]. Seed exchanges are nothing new, and distribution relations among seed savers to share seed varieties have existed between neighbors, within communities, across great distances, and over generations. Despite a growing number of seed savers and scholarly attention to the seed saving practices in the north American context, seed saving and exchange is still a less popular practice than it once was, and there is a need to understand the implications of seed saving for the global North, which is both related to and distinct from those applicable in global South contexts (Ott Whealy 2011; Nazarea 2005).

Drawing on the literature, the reports and websites produced by the organizations, the paper first discusses the significance of agrobiodiversity and seed exchange networks for food system resilience for the United States' food system. Seed systems represent the social and ecological aspects of the food systems, and continued access to seeds strengthens farmers' livelihoods and food security. It then examines civil society, business and hybrid models that aim to improve farmers' access to open-pollinated and regionally adaptable seeds. Despite the differences in their goals and methods, these initiatives fulfill an important conservation and scientific role for conservation and use of open-pollinated varieties, which is one of the key components for building resilience of the American food system.

Seed systems and resilient agriculture

Resilience and vulnerability are central in understanding social-ecological change and the challenges of sustainability. Resilience and vulnerability can be better assessed based on multiple stressors, e.g., a combination of the processes of economic liberalization, climate change, institutional failures and other environmental dynamics, that interact with socio-political factors to influence human vulnerability (See Hodbod and Eakin 2015). Vulnerability is defined more as a condition that encompasses characteristics of exposure, susceptibility, and coping capacity,

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[2] Several studies discuss direct farmer-to-farmer seed exchanges and their impact on food security, resilience, farmers' livelihoods and genetic diversity. For research in the United States, see Campbell (2012) for a study of farmer-to-farmer seed exchanges in Ozarks in Arkansas, and Veteto (2014) and Best (2013) for such exchanges in southern and central Appalachia. There is a growing scholarly literature on global cases as well: Fuentes et al. (2012) discuss the impacts of farmer seed exchanges on quinoa genetic diversity in Chile. Calvet-Mir et al. (2012) discuss significance of seed exchange among home gardeners for agrobiodiversity conservation in Catalan Pyrenees, Iberian Peninsula. Whereas da Via (2012) discusses how the exchange of locally adapted seeds has become a focal site of grass-roots organizing in the rural areas of Europe, Pautasso et al. (2013) presents a general review.

shaped by dynamic historical processes, differential entitlements, political economy, and power relations (Eakin and Luers 2006). Discussions about seed system resilience also reflect the intersection of social and ecological systems. Whereas the initial discussion of seed system resilience is framed around the integration of informal and formal seed sectors to overcome barriers of production (Bellon et al. 2011), recent studies emphasize the interplay of bio-physical features and institutions, cross-scale linkages and social memory among other features (Folke 2006; Robinson and Berkes 2011). This holistic perspective allows moving beyond the material, the seed, and its productivity, towards management of a limited natural resource in a manner that enhances its long-term viability and integrity. Because seed systems refer to "all practices and institutions that are involved in plant breeding and seed provision, as well as the related legislation, " seed systems entail the actors, institutions, processes, and knowledge involved in the development, certification, propagation, distribution, exchange and utilization of seed (McGuire 2008: 274). Thus, an assessment of the institutions, relationships, and knowledge that span formal and informal seed systems are crucial for building resilience because the knowledge required to select and save seed and the infrastructure for exchanges are social resources that if lost may be difficult to re-establish (McGuire and Sperling 2013; Heinemann et al. 2014; Carolan 2007).

The seed is a key input for agricultural production and a carrier of valuable genetic resources. Access to seeds, and thus, crop genetic resources, is the foundation of food production, and the biological basis for food security, livelihoods and economic development. Crop genetic resources also act as insurance for farmers and humanity to adapt to current and future ecological challenges and future food security depends on their conservation (FAO 2010; Andersen and Winge 2013). Farmers may cultivate and use different crop varieties, including traditional or heirloom varieties, for commercial or non-commercial production and as a form of insurance against agro-ecological risks. They may grow different varieties of the same crop to serve multiple purposes (e.g. for animal feed, markets or household consumption), to fit to different ecological niches (e.g. different wheat varieties suitable for hillside or valley bottom) or to benefit from particular strengths (e.g. resistance to pests, early maturity at higher altitudes). Thus, the diversity on the farm and in the farmer communities ensure access to new seeds when one crop fails, seeds no longer provide enough yield, or farmers believe that seeds no longer meet their expectations of yield, taste or sales at the market. Diversity at genetic, species, agro-ecosystem and landscape levels and diversity of social mechanisms thus can help farming households and communities to meet their livelihood needs in times of seasonal shortage and in times of economic and ecological crises (Brush 2000; Pautasso et al. 2013; de Boef et al. 2013).

Seeds are key inputs for agricultural research and development to improve valuable traits to meet current and future challenges, to produce higher yields and to improve resilience against pests, diseases and extreme climates. Wild botanical relatives of food crops may contain genes that allow them to survive under stressful conditions. Plant breeders have successfully drawn on genetic variation and certain traits found in crops grown in different parts of the world helped to bolster agricultural research and development particularly in the United States and in the world. The cultivation and mass production of tomato, for example, has benefited from its wild relatives, native to the Andean region of South America (Qualset and Shands 2005). Today, as new and re-emerging pests and diseases threaten to damage or even wipe out certain crops, changing climatic conditions create uncertain growing conditions and the market demands new and improved crop varieties, a failure to maintain the genetic diversity in crop species could have staggering consequences for both American and global agriculture. Pests and plant diseases are conservatively estimated to cost $20-$33 billion each year in the United States. Moreover, new global epidemics such as the wheat rust in Africa and Asia may have repercussions for wheat varieties in the United States (Qualset and Shands 2005). Greater social and ecological diversity provide better prospects to enhance the system's capacity for self-restoration (Marten and Matthews 2009). A recent USDA report on climate change effects on American agriculture states that increases of atmospheric carbon dioxide, rising temperatures, and altered precipitation patterns will affect agricultural productivity: The benefits of increasing carbon dioxide will be outweighed by increases in temperature, and variable precipitation, and extreme climate conditions, such as dry spells, sustained droughts, and heat waves are likely to reduce productivity of crops (Walthall et al. 2012). A diverse mixture of seeds of an annual crop has a better chance of surviving and maintaining yield under changing climatic conditions compared to genetically uniform seeds. Particularly, if some of the elements of these mixtures include early-maturing, short-cycle crop varieties planted during brief wet seasons to reduce demand for irrigation or several varieties of the same or related species planted in the same fields, then it can provide a "model for using a diversity of agricultural crops resilient enough to fend off the threats of climatic disruption" (Nabhan 2013: 178) Similarly, diversity of perceptions, values, knowledge, technology, social organization, and social institutions provide opportunities for better choices: In the seed systems, diversity of breeding methods used, crops planted and exchanged, varieties propagated and improved present these opportunities to enhance resilience. However, several trends heighten risk factors and reduce the resilience of agri-food system globally and in the U.S.

Risk factors and seed systems in the United States

Genetic resources are unevenly distributed in the world, and maintaining continued access to such genetic material is a global concern. In terms of agrobiodiversity, United States has not been considered a major center of crop plant diversity, but more than 20,000 species of plants, or about 7% of the world's flora, are native or naturalized in this region and approximately 4000 plant species have been introduced since the Colombian Exchange (Khoury et al 2013). These exchanges helped to sustain the diets and food security in the United States, and despite the fairly small number of crop wild relatives native to the United States, their diversity has potential value for agricultural research and development. The relatives of a complex of Mesoamerican crop species, including corn, a number of bean (*Phaseolus*) and squash species, chili pepper (*Capsicum*), American cotton (*Gossypium hirsutum*), and tobacco (*Nicotiana rustica*), are distributed in the southern regions of the United States, and several well-documented examples of use of native crop wild relatives in breeding exist (Khoury et al. 2013). However, there are concerns about access to seeds in the United States—not only moving beyond the dominance of hybrid or genetically-engineered (GE) seeds but also access to open-pollinated seeds in general, and being able to exchange them in particular.

Concentration in the seed industry and regulatory mechanisms to protect patents and intellectual property rights have implications for farmers' access to seeds and breeding complex traits since these changes have isolated farmers from the seed saving, exchange and plant breeding processes. In the United States, the seed sector is dominated by large corporations, which have created one of the most concentrated industries in agriculture. For example, the four largest companies accounted by about 72% of U.S. market for corn (maize) seeds in 2007 and 55% of U.S. market for soybean seed (National Research Council 2010). Seed expenditures by U.S. farmers grew exponentially since 1960s, which can be explained by increases in the share of seed purchased by U.S. farmers from commercial sources (Fernandez-Cornejo 2004). However, the one-size-fits-all logic of the marketplace influenced the plant breeding to be geared towards vertical resistance," seeking out the specific genes to confer quantifiable improvements for a specific problem such as stem weakness or blight" rather than adaptation to regional growing conditions (McDorman and Thomas 2011). Moreover, there has been an increasing investment in molecular breeding programs that "do not adequately support the development of complex traits necessary for adapting seed to regional needs," thereby undermining support for classical breeding (National Organic Coalition 2013). Detailed regional analysis of climatic changes and associated impacts in the United States suggest that the degree of change is quite different depending on the location. Coupled with extreme regional specialization in food production, these climatic variations require diversity to enhance adaptive capacity and the resilience of the U.S. food supply (Walthall et al. 2012; Nabhan 2013; Lengnick 2015).

As the monopolization of the U.S. seed sector and stricter implementation of patents and patent-like plant variety protections continued in 1990s, seed saving and exchanges, and with it on-farm capacity that contributes to innovation, have shrunk (Heinemann et al. 2014). The economic and legal context has also facilitated this consolidation. The seed "remains the most research-intensive of the agricultural input sectors" and private-sector firms have been able to capture more value from seeds through both technological innovation in the form of modern biotechnology and changes in property rights (Fernandez-Cornejo et al. 2014: 3). Today, major crops dominating the U.S. agricultural landscape are genetically engineered. Whereas biotech firms continue to develop new GE seed varieties at a fast pace, U.S. farmers continue to adopt them at a similar robust rate. Particular emphasis has been on seed varieties with multiple (stacked) traits to delay resistance in weeds and pests, and in recent years on varieties with agronomic properties such as drought resistance. The number of GE seed variety commercial releases grew from 4 in 1985 to 1,194 in 2002, and continued to grow with an average of 800 new varieties per year since then (Fernandez-Cornejo et al 2014). While recognizing the incremental impact of biotech plant breeding on productivity of U.S. agriculture, the National Association of Plant Breeders (NAPB) also urges to focus on transformative approaches toward improved sustainability and to recognize the cumulative changes of conventional breeding. One concern related to private sector plant breeding with a focus on GE varieties is that it does not meet "the needs of growers, society or the environment" in certain regions or some species (NAPB 2013: 3). Thus, NAPB suggests a model of plant breeding that will support innovation to reduce long-term risks and to educate and train next generation of plant breeders. Another concern is the cost associated with sustaining and enhancing annual crop yields under hotter drier conditions with GE "climate-friendly" or "drought-ready" crops: The estimate costs can be more than $5 million and 10-15 years of research and development to genetically engineer seeds to adapt to climatic changes, and more money will be spent on "seed patenting, grow-outs, marketing, and packaging" to get each of those GE cultivars into the fields (Nabhan 2013: 173).

The expansion of GE crops is also a concern for organic farmers. Particularly, access to "safe" seeds, free from transgenic contamination is a pressing issue.[3] Disagreements over GE crops are not merely disagreements about the scientific evidence of risk but about social order and what kind of agriculture organic farmers want (Kinchy 2012). Disagreements also stem from concerns over protecting organic markets, and the apparent imbalance regarding intellectual property rights in case of cross-pollination (Ronald and Fouche 2006): Organic farmers bear the costs of contamination at the market and farm level, and the company producing GE seeds "appears to be under no legal obligation to prevent its genes from getting where they are not

[3] Although the first National Organic Program (NOP) proposed in 1997 did not prohibit GE organisms in organic agriculture, the second NOP in 2000 excluded the use of GE organisms in certified organic production and handling However, at present there is no policy regarding the unintended (adventititious) presence of GE material in organic products or food, "consistent with the fact that organic production is process-based and not product-based"(Ronald and Fouche 2006).

wanted" (Kinchy 2012: 125). For crops with GE counterparts, such as corn, soybeans and canola, GE material turns up in the fields where GE seeds are not planted[4]. In 1999, an organic seed company, High Mowing Organic Seeds guided a coalition of other seed companies to draft a statement about a stance on GE agriculture. Over 70 entities, seed companies and civil society organizations, have signed the statement, *Safe Seed Pledge*, to confirm their commitment to not to knowingly buy or sell GE seeds or plants to protect the foundation of agriculture, seeds and livelihoods as a genetically stable source for future generations (HMOS 2014).

Farmers, activists, scholars also voice concerns about erosion of diversity in agricultural landscapes that limits the scope of potential future evolution, agricultural sustainability and resilience of food systems. Domestication and artificial selection have reduced species diversity drastically, and modern agriculture and crop breeding have developed a restricted number of pure or hybrid lines that have reduced genetic diversity (Loueille et al. 2013). A few crop varieties, particularly, corn and soybean, have replaced the diversity of crops found in farmers' fields in the United States and globally, and this uniformity increases the risk of an unforeseen pest or disease and climatic changes[5]. Globalization, particularly increased volume of food imports and global travel also amplify the risk of accidental introductions of plant pests. The continental U.S. today hosts more than 2,000 species of non-indigenous insects and mites, which are responsible for an estimated $14 billion in annual crop losses. In addition to accidental introductions, concerns about national security now also include threats of intentional plant and pest introductions in the American agriculture. These concerns are exacerbated with climate change, which may present new challenges to crops and enable pests to expand into new regions (Qualset and Shands 2005).

Climatic and environmental change also bring forth the need to breed new and improved varieties with diverse agronomic traits to be adaptable to shifts in regional conditions. To maintain high levels of agricultural productivity, plant breeders need access to a supply of germplasm with diverse genetic characteristics. While plant breeding in the United States is carried mainly through germplasm gathered in collection missions from all over the world that is

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[4] Corn, cotton and soybeans make up the majority of the acres planted to GE crops in the United States and the majority of field releases approved by USDA's Animal and Plant Health Inspection Service. However, GE vegetable seeds such as potatoes, tomatoes, squash are also commercially available in the markets (Fernandez-Cornejo et al. 2014).

[5] Recent findings about the expansion of GE agriculture and its impacts, particularly western corn rootworms in the United States developing resistance to the natural pesticide in Bt corn align with the reports of field-evolved resistance for some of the 5 of 13 major pest species globally, such as cotton ballworm resistance to Bt cotton in China (Gassman et al 2011; Tabashnik et al. 2011).

stored *ex situ* in gene banks or seed banks (Qualset and Shands 2005), farmers who continue to propagate traditional varieties of crops provide an important service for *in situ* conservation of agrobiodiversity. *In situ* conservation incorporates indigenous knowledge, crop-pest co-evolution and security through redundancy and decentralization (Abbott 2005). Crop scientists and human ecologists suggest that *ex situ* conservation alone is not sufficient but can be a complementary approach to *in situ* conservation because genetic diversity of crops evolve differently under *in situ* and *ex situ* conservation mechanisms (Brush 2000). For *ex situ* conservation, particularly for genetic material conserved in seed banks and gene banks, the concern is to facilitate utilization to ensure continued use (Solh and Saxena 2010). For *in situ* conservation mechanisms, particularly on-farm cultivation in farmers' fields, the concern is to integrate the information necessary for selecting, cultivating and harvesting the particular varieties with markets. Since conservation of crop wild relatives both *in situ* and *ex situ* are neglected and have problems (Heywood et al. 2007), sustaining the capacity and rights of farmers as agricultural stewards, including the ability to save, own and sell seeds, becomes particularly important for the resilience of food systems. Similarly, access to seeds is an important concern because only a few seed sources continue to exist for traditional cultivars, and this highlights the importance of formal and informal seed exchange networks (Ashworth and Whealy 2002; Nabhan 2008).

Last but not least, the changing profile of American agriculture, particularly the aging of farmers, shrinking of farming population and consolidation of large farms, undermine the diversity of knowledge required for building resilience in the seed systems. According to 2012 Agricultural Census, the average age of American farmer has continued to increase and is now 58.3 years. The total number of farms has fallen down 4.3% from the previous Census in 2007 and reached 2.1 million farms, reflecting a long-term trend of fewer farms involved in agriculture (USDA 2014). Even for the exchanges that occur in formal markets, seed circulation is a social process and farmers' knowledge practices related to remembering, comparing and knowing the varieties are crucial in seed saving and exchange (Pautasso et al. 2013). Thus, documenting and facilitating the protection of such knowledge from disappearing becomes an important element of seed exchange networks. Those involved in seed exchange networks discussed below serve multiple goals and move beyond juxtaposing heirlooms against GE seeds. The goals, such as promoting heirloom gardening, reviving a more grass-roots approach to seed breeding as an alternative to corporation control in the seed industry, breeding high quality varieties for regional markets and for heterogeneous environments in low-external input systems demonstrate the complexity of building resilient seed systems.

Seed libraries revive seed exchange at the grassroots level

Globally, the consciousness among nonprofit actors about the importance of genetic resources for food and agriculture has been at an all time high. Civil society, indigenous peoples and new social movements, alone or by mobilizing other actors have been at the forefront of alternative food movements: They enable conditions for conservation of crop genetic resources by creating an economic value for agricultural biodiversity and pressing for governance reform and institutional change by building tri-sector partnerships with government and business or facilitating demands for reform (Rands et al 2010). They can also guide capacity development of farmers and other actors working with community-based institutions. Although there exist multiple civil society organizations and grassroots initiatives working for conservation of seeds, the newcomer seed conservationists often find the seed saving idea much more complicated than it first appeared. Thus, the growing network between existing and new initiatives become particularly important to sustain, guide, and encourage them and to establish models that can be replicated elsewhere. Seed libraries operating through public libraries, churches and other places of worship, cooperative extensions, private homes and museums in 46 states are one of these newcomers (Richmond Grows 2015).

Following the establishment of Bay Area Seed Interchange Library (BASIL) in 2000, over 400 seed libraries have flourished in 46 states in the United States. Seed libraries are institutions that lend seeds or share them with the public. Their collections, seeds that will be exchanged, are often acquired through donations from members, who are typically gardeners and farmers that harvested the seeds from their own plants, or purchased them from seed companies. Seed libraries may have different rules about borrowing and lending seeds depending on the needs, growing conditions, abilities, and interests of their community. Whereas some seed libraries, such as East Palo Alto, do not ask patrons to return seeds, others, like the Jenkinstown Library in Pennsylvania, allow patrons to borrow seeds only if they intend to return saved seeds after growing and harvesting them (HVSL 2013).

Seed libraries may function differently. Yet, they overlap in their emphasis to bring open-pollinated varieties back into the public domain (McDorman and Thomas 2012). According to Ken Greene, “seed libraries are an experiment in participatory seed breeding” (HVSL 2013). If more people save seeds in a specific community, the seed will become more adapted to that area. To facilitate seed independence and develop regionally adapted seed varieties, seed libraries are asking consumers to become “cooperative producers”. By providing clear guidelines to return seeds, such as keeping journals of growing conditions, proper labeling, and not sharing hybrid seeds (unless clearly labeling them), they are also asking gardeners to take more responsibility in the local seed sovereignty movement. They also provide ongoing trainings and meetings to make sure that seed savers choose seeds they can successfully save (Richmond Grows 2015).

To sustain themselves, seed libraries must facilitate the exchange of quality seeds. Due to lack of the permanent staff or materials to test germination rates and disease, many seed libraries rely on the patrons to exchange healthy and viable seeds. They provide guidelines to ensure exchange of healthy plants that have genetic diversity and breed "true to type". However, the existence of such guidelines was not adequate to deter the Pennsylvania Department of Agriculture's warning of the Simpson Public Library in Mechanicsburg with a letter that the seed library would violate the state's 2004 Pennsylvania Seed Act if patrons exchanged seeds without a seed license and required germination tests (PA DOA 2014). According to Pennsylvania seed Act, "all seed being distributed in Pennsylvania must be labeled according to the Pennsylvania Seed Act and regulation. This includes, but [is] not limited to" such things as Germinate Test date and "Sell by" date. Moreover, the harvested seed being returned to the library must also be labeled with the testing information before distributing them. Seed libraries were thus faced with the risk of being shut down due to violation of state seed laws. To ensure exchange of high quality seeds, some seed libraries, such as the SPROUT Seed Library in California, sees seed quality concerns as both learning opportunities and the responsibility of members who are encouraged to report any issues and pull seeds from the collection when necessary (HVSL 2013).

Other initiatives within the seed exchange networks have helped seed libraries to facilitate sharing locally grown and saved seeds: Clif Bar Foundation, Richmond Grows Seed Lending Library and Sustainable Economies Law Center have started a national petition campaign to change seed laws. Seed Savers Exchange (SSE) has also voiced its support for seed libraries and advised them to follow best practices, not to share very old seeds and organize seed saving schools (SSE 2014a). Moreover, SSE has started to include workshops for community seed programming on how to start a seed bank or a seed library in a community through their annual conference and education activities (SSE 2014b). Since 2011, seed libraries also network at national scale. The networking started with the facilitation of the University of California at Santa Cruz Demeter Seed Saving Project, Native Seeds/SEARCH and Richmond Grows Seed Library[6]. The outcome is a website (SeedLibraries.org) that serves as a national network to share

[6] The coordinator of the national network is Rebecca Newburn, who is a permaculturalist and math and science educator, and a member of a transition town initiative in Richmond, CA. The transition initiative is a global movement that aims to build resilient communities through local projects such as food, transport, energy, education, housing, waste and arts to address the global challenges of climate change, economic hardship and shrinking supplies of cheap energy (Transition Network 2009). Established in 2010, the Richmond Grows Seed Library's model provided a framework that could be replicated, which was crucial in the expansion of seed libraries in the United States (Conner 2014)

resources, inventories and education materials on seed saving, seed swaps and other aspects of seed sovereignty (Richmond Grows 2015). Similarly, in May 2015, Native Seeds/SEARCH together with Pima County Public Library, the University of Arizona, Edible Baja, SSE and the Community Food Bank of Southern Arizona has organized the first International Seed Library Forum to "coalesce efforts by public libraries, nonprofit organizations, universities, and food banks to increase the quality and diversify the means of managing community seed resources with free or affordable access to low-income households." (Nabhan 2015) During four days, experts and practitioners from nine countries discussed promising practices for seed libraries, food justice, cultural seed stories, educational opportunities, seed policy, as well as exchanged seeds. The focus was not only on how to publicize seed libraries and grow the seed movement but also how to address regulatory challenges seed libraries face[7] (Arizona Library Association 2015).

Seed companies develop and market new varieties

The focus on seed libraries also intersects with the potential of these initiatives to transition into seed business. One particular example is the Hudson Valley Seed Library that started in 2004 as part of a public library in Gardiner, NY. Together with local farmers, nonprofit organizations and Cornell University, Hudson Valley Seed Library, now a company, produces majority of its seeds on its Northeast Organic Farmers Association New York certified organic farm. Its online sales include "library packs," seeds grown locally and by members, and "garden packs," heirloom seeds bought from wholesalers (New York Times 2010). Reviving the Otto File flint corn serves the Hudson Valley Seed Library's overall mission to conserve agrobiodiversity in order to reduce vulnerability due to monocultures and global climate change to help gain self-sufficiency of the seed supply and to achieve regional food security in the United States (HVSL 2011). Working closely with organic farmers in the Northeast who seek plant varieties adapted to low-input systems and to meet their diverse needs, it also aims to develop organically and regionally bred seeds (HVSL 2013). Hudson Valley Seed Library is also interested in reviving traditional knowledge, and place-based food traditions to serve the purpose of localization, where traits like flavor are given top priority, and less emphasis is placed on standardized shapes, sizes or the ability to be picked unripe and shipped long-distances. While conserving and developing heirlooms, it particularly works to put them into utilization so that

[7] In one of the sessions on regulatory challenges, Neil Thapar from Sustainable Economies Law Center provided updates on the "Save Seed Sharing" National Petition Campaign, whereas Neil Hamilton from Drake Law School, Iowa, discussed the legal context that could prevent public exchange of seeds. For more videos of the International Seed Library, see Pima County Public Library (2015).

heirlooms will not be preserved as antiques but will be used and adapted to new climates. Thus, it works closely with organic farmers associations to expand marketing opportunities for new heirloom and open-pollinated varieties (HVSL 2013), also a focus of other organic seed companies.

Another seed company working with open-pollinated is a Vermont company, High Mowing Organic Seed Company. As of 2015, it offers over 600 heirloom, open-pollinated and hybrid varieties of vegetable, fruit, herb and flower seed to home gardeners and commercial growers nationwide (HMOS 2015a). Although the USDA organic regulations require that "organic producers use organic seeds, annual seedlings, and planting stock," they also allow producers to use non-organic seeds when equivalent organic varieties are not commercially available (NOP 2013). High Mowing Organic Seeds aim to address the gap and has worked "to produce, develop and sell only the best quality organic seeds for varieties selected for their exceptional performance in organic conditions" (HMOS 2015a). Both Hudson Valley Seed Library and High Mowing Organic Seed companies ensure production of high quality seed with their on-site germination tests. Like Hudson Valley Seed Library, High Mowing Organic Seeds engages in trials and a breeding program to assess and develop varieties that thrive in organic conditions. While it aims to cater to the demands of organic farmers in their quest for diverse varieties that will thrive in low-input conditions, High Mowing Organic Seed company also believes that the increased demand for organic seed will encourage more companies and universities to devote resources to develop new organic varieties (HMOS 2015c). While it produces much of the seeds it sells on its farm, it also works with farmers across the United States, from Vermont, New York, Idaho, California and Oregon, and wholesale seed companies to produce seeds for the company[8].

Education and advocacy have also been crucial for High Mowing Organic Seeds. As the designer of Safe Seed Pledge, it has reached out to more than 70 companies, such as Hudson Valley Seed Library, to sign commitment to distribution of non-GE seeds, and it has also become one of the first seed companies to be non-GE verified. Because it perceives seeds as a tool "to

[8] For instance, some of High Mowing Organic Seeds' salad lettuce varieties are grown by an organic farmer and plant breeder, Frank Morton, who owns Wild Garden Seeds in Oregon (HMOS 2015b). Tested to become resilient under low-input agriculture conditions, these lettuce varieties also integrate color, texture, and taste so that they could be "hearty enough to be shipped cross-country in unrefrigerated UPS trucks for forty-eight hours, but also beautiful and flavorful enough to be served at the finest restaurants" (Seed Matters 2015)

teach and empower kids and adults about food security and nutrition" (HMOS 2015d), it has donated more than 200,000 seed packets to education farms, community gardens, senior centers and seed libraries. Seed donation is a practice that is also implemented by other initiatives such as the Hudson Valley Seed Library and Native Seeds/SEARCH to expand access to seeds and facilitate awareness, knowledge and seed utilization. Through collaborations with universities, Clif Bar Foundation, Organic Seed Alliance, and Open Source Seed Initiative, High Mowing Organic Seeds has facilitated workshops, trained farmers, gardeners and communities in seed saving and became an advocate for seed sovereignty. These collaborations among business, civil society and higher education demonstrate the role of partnerships and networking to build and improve a resilient seed system, a model that SSE and Native Seeds/SEARCH also followed.

Business and civil society models ensure financial and social sustainability for seed exchanges

Farmer-to-farmer seed exchange and local plant breeding through farmer selection have continued to decline over time in American agriculture. Whereas legal mechanisms, such as the 1930 Plant Act and 1970 Plant Variety Protection Act imposed limitations on farmers' rights to save and exchange seed, the industrialization of agriculture and the centralization of the seed industry also opened a niche for civil society initiatives and small seed companies: SSE was established in 1975 in Iowa and Native Seeds/SEARCH was founded in Tucson in 1983, reflecting concerns of individual gardeners, scientists and local communities for disappearing diversity and seeds. These initiatives that have both a civil society and business component have also collaborated closely with each other and a network of seed business and organizations that emerged after a 1985 national conference that focused on "finding and marketing seeds adapted to their own regions." (McDorman and Thomas 2011)

The SSE established in Decorah, Iowa, works "to conserve and promote America's culturally diverse but endangered garden and food crop heritage for future generations by collecting, growing, and sharing heirloom seeds and plants." (SSE 2013) Since 1975, it has encouraged a participatory conservation and breeding model to produce a genetically diverse food supply. By encouraging "backyard preservationists" to find regionally adaptable varieties, it aims to source material for localized breeding projects. On its 890-acre Heritage Farm, it operates an education and visitor center, preservation gardens and a historic orchard (Carolan 2007). Although seed exchange is limited to national and international members, its seed schools cater to a diversity of interested parties, and anyone can purchase their seeds through their catalog and retail store (SSE 2014a).

SSE's seed acquisitions have come from donations from individuals, duplicates of accessions collected by other civil initiatives such as Rodale Research Center and Wanigan Associates, and purchases of endangered varieties from commercial catalogues to maintain them in their central collection (Ott Whealy 2011). SSE's current plant acquisition policy prioritizes open-pollinated seeds, propagated crop of U.S. heirlooms, and historic non-hybrid commercial varieties (SSE 2014c). The plant accessions have been catalogued with their ecological characteristics and cultural stories and shared among members through newsletter and seed catalogues, annual face-to-face meetings and conventions, and online (Whealy and Adelman 1986; Ott Whealy 2011). Once granted a nonprofit status, SSE has had access to grants to continue its seed exchange activities. Until its move to the current location in 1995, SSE relied mainly on its members for propagating the seeds. Now, the Heritage Farm, collaboration with University of Wisconsin and members as part of citizen-science Member-Grower Evaluation Network (M-GEN) enables SSE to propagate existing and new regionally adapted varieties, as well as to serve the culinary preferences of gardeners in different parts of the country[9] (SSE 2013)

Since its foundation, SSE has actively engaged in seed advocacy, first against the Plant Variety Protection legislation by congressional statements, by training and organizing other farmers, activists, and institutions, by exchanging heirloom seeds with other organizations, and then by building a network among nonprofit organizations, seed companies and scientists (Whealy and Adelman 1986). Educational programs have always been an important focus for SSE to facilitate farmer-to-farmer learning.[10] SSE has partnered with other organizations, particularly with Native Seeds/SEARCH on projects such as Renewing America's Food Traditions (RAFT) to document and reintroduce traditional culinary practices and America's top ten endangered foods from chiltepin pepper to marshall strawberry (Nabhan and Rood 2004).

SSE complements *ex situ* and *in situ* conservation: Its seed collection from members and other organizations is permanently stored as backup and for revival purposes at the USDA Seed Bank in Fort Collins, Colorado, and at Svalbard Global Seed Vault in Norway (SSE 2014c; Whealy and Adelman 1986), both of which are dedicated to long-term storage of seeds under

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[9] In 2013, SSE grew 1,115 heritage varieties of 40 different crops, added 350 varieties to orchards and grafted 1,462 new apple trees in Heritage Farm. M-GEN provided access to the home gardens of 74 members from Alaska to Florida who grew and documented 15 varieties of bean, corn lettuce, mustard, pepper and tomato (SSE 2013).

[10] In 2013 alone, over 200 people participated in SSE's seed saving workshops, 15,000 people visited the Heritage Farm, 500 people attended heirloom apple tasting event and annual conference and campout (SSE 2013).

cryogenic conditions[11]. One of the largest seed banks in the world, it maintains an *ex situ* collection of over 12,000 heirloom varieties of vegetables, fruits and grains. SSE has several facilities for short and medium term seed storage, including humidity-controlled drying rooms, cool storage seed vaults, a potato tissue culture lab, a root cellar to overwinter biennials, an underground walk-in freezer as a protection against tornado or fire in the main building, and its garden that serves both to propagate the seeds and to educate visitors (Ott Whealy 2011). It is one of the first signatories of the Safe Seed Pledge in 1999 (SSE 2014b), and currently about 50% of the seeds it distributes through its catalog are USDA organic certified. In terms of finances, the sales and shipping of seeds provide about 76% of its annual revenues and about 7% comes from membership (SSE 2013).

Similarly, Native Seeds/SEARCH that conserves, distributes and documents diverse varieties of agricultural seeds and their wild relatives in Southwest U.S, and northwest Mexico since 1983 with the goal of strengthening regional food security. With a particular emphasis on traditional knowledge, it has a seed bank which includes approximately 1,900 different accessions of arid-land adapted agricultural crops, many of which rare or endangered and have been "utilized as food, fiber and dye by the Apache, Chemehuevi, Cocopah, Gila River Pima, Guarijio, Havasupai, Hopi, Maricopa, Mayo, Mojave, Mountain Pima, Navajo, Paiute, Puebloan, Tarahumara, Tohono O'odham, Yaqui, and other cultures" (Native Seeds 2015a). It propagates, sells and freely distributes over 500 plant varieties from its collection grown at its Conservation Farm in Patagonia, Arizona, alongside its online and retail store in central Tucson, annual seedlisting and its recently established seed library (Native Seeds 2015b).

Native Seeds/SEARCH's seed acquisitions have come from individuals, specific scientific seed collection led by academicians and universities as well as from native American communities. Native Seeds/SEARCH provides seeds of only open-pollinated varieties, that are landrace or heirloom varieties with a long historical connection to the Greater Southwest. Over half of the accessions are comprised of corn, bean and squash (Native Seeds 2015a). Like SSE, education has been an important mission of Native Seeds/SEARCH. Through its flagship education program, Seed School, Native Seeds/SEARCH organizes public lectures, roundtable discussions, workshops and seed saving schools, "to empower people to become partners" in

[11] Seed Bank in Fort Collins, CO, is federally owned. It serves for the preservation and protection of plant biodiversity and as a backup location for all other national genetics collection locations in the United States. It provides seeds for research and educational purposes worldwide. Not only Seeds Savers Exchange, but private companies such as Monsanto and Dupont can also store their seeds in its vaults (NPR 2013b) While USDA Seed Bank in Fort Collins and Svalbard are autonomous entities, the off-site deposits of the SSE remain its property (SSE 2014c)

their work “to conserve biodiversity and develop regional seed sovereignty”. The immersion program incorporates the science, business and craft of seeds with a political economy of the seed industry “so that graduates are informed seed citizens” (Native Seeds 2014c). In recent years, it has broadened its geographical scope: With its participants from across the country and around the world, the Seed School aims to provide “missing pieces” in seed knowledge that is crucial to build regional seed solutions (Native Seeds 2014c). Seed School has now moved to the Rocky Mountain Seed Alliance, and it will be organized in different parts of the United States, partnering with higher education institutions to facilitate community based models of seed stewardship.

Native Seed’s definition of food system resilience builds on both the social and natural aspects of agriculture. It proposes conservation and use of agrobiodiversity to reduce vulnerability in an uncertain and changing environment, particularly to strengthen regional climate change adaptation, and to sustain indigenous seed sovereignty[12]. (Native Seeds 2014b). Through Native American Free Seed Program, Native Seeds/SEARCH provides free seeds (in limited quantities or at half-price) to Native American communities residing in the southwest and elsewhere (Native Seeds 2015c). In 2012, it established Arizona’s first seed lending library within its retail store to distribute locally adapted seeds and increase regional seed sovereignty. Native Seeds/SEARCH has also been an advocate for seed libraries and other initiatives such as Hudson Valley Seed Library seed company.

Conclusion

As the work of these initiatives demonstrates, the seed exchange networks help to bring the problems in the seed industry to the attention of the public. By reaching to different interested parties, from 1,400 people as lifetime members of the SSE (SSE 2014d) to the several

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12 There exist other Native American groups working on food and seed sovereignty. Traditional Native American Farmers’ Association and New Mexico Acequía Association formed New Mexico Food and Seed Sovereignty Alliance (NMFSA) and have organized national workshops and conferences since 2006, NMFSSA also passed Seed Sovereignty Declaration and was successful in introducing a State Joint Legislature in New Mexico that recognized “the importance of indigenous agricultural and native seeds to the food security of New Mexico as well as recognizing farmers’ rights to keep their seeds free from genetic engineering contamination” (NMFSSA 2014). In 2013, a new organization, Native American Food Sovereignty Alliance was formed, which aims to become a sustainable movement “that is Native American driven and controlled, nationally active and dedicated to addressing food security, hunger and nutrition in Native American communities at the national, tribal and local levels” (NAFSA 2014).

people that have just started to use seed libraries for their gardens and the growing clientele of organic seed companies, such initiatives broaden the conversations about seed sovereignty and access to seeds, as well as farmers' role in the conservation and use of agrobiodiversity in the United States. Whereas these initiatives may emphasize different goals, they aim to enhance resilience under environmental and climate uncertainty and present an alternative to the power dynamics in the seed systems that affect food and seed sovereignty.

Seed exchange networks fulfill an important role in sustaining food system resilience by connecting *in situ* and *ex situ* conservation mechanisms, closing the gap between plant breeding, and providing seeds for diverse needs of farmers interested in sustainability and low-input agricultural systems. Traditionally, seed exchange systems have been local. The heirlooms were grown, used and adapted to new climates as people brought seed with them when they moved from one place to the another (Chambers and Brush 2010). Similarly, some of the successful partnerships between plant breeding programs at universities, nonprofit organizations, small seed companies, and farmers to develop varieties for organic agriculture that have emerged in recent years often start on a local level. Although trial networks may exist at the national level, and varieties may do well in multiple regions, the distinguishing characteristic of initiatives highlighted above is that they started at local and regional scale by scaling up and building further networks.

These initiatives serve multiple functions and goals. First is the conservation of agricultural biodiversity and provision of opportunities for farmers' participation in plant breeding. These initiatives function in a network and collaborate with each other to complement each other's work: They collect seeds (from members or exploration trips), regenerate them *in situ* or store them *ex situ*, enable conditions for their distribution (either for a fee or for free) to broaden access to open-pollinated varieties. The agricultural landscapes of the United States present a wide variety of geographical and climatic conditions, and some farmers are concerned that the varieties adapted for monocultures and bred by the commercial sector may not capture this diversity. By engaging farmers in the propagation through participatory processes or shortening the feedback mechanisms between the customer and the breeder, these initiatives present an alternative to industry-led plant breeding processes. Similarly, locally adaptable and diverse seeds present ecological diversity, which will reduce risks and vulnerabilities by sustaining diversity in the fields (MacFall et al. 2015) The *ex situ* collections also serve as a backup while these initiatives aim to revive cultural traditions and reintroduce the seeds back into communities.

Second, these initiatives help to address the information gap of farmers and gardeners on plant breeding through their education and outreach activities, including seed saving schools, workshops and public lectures. The sharing of information on producing sustainable and organic seed as well as improving open-pollinated varieties help to sustain social aspects of agrobiodiversity conservation as a part of nature that represents the interdependence between social and ecological systems. Educating farmers and communities on seed saving helps to conserve seeds in the long run. These approaches fit well with the broader goal of complementing *ex situ* conservation with *in situ* conservation and maintaining farmers' knowledge as plant breeders.

In general, the seed exchange networks have been successful at bringing heirloom fruits and vegetables to the attention of general public through their catalogs, at-garden centers, chefs using them, articles in media, scholarly work and journals devoted to heirloom varieties (Volkening 2006). Through declarations, public hearings, collaborations between scientists, business, the state and civil society, these initiatives have also advocated for seed and food sovereignty. They have brought back several open-pollinated varieties that have provided livelihoods and adapted well to regional conditions in the United States, which can provide resilience against environmental changes. For instance, tepary beans, desert relatives of pintos, limas and runner beans in Native Seeds/SEARCH collection that have been grown by more than 30 native and immigrant cultures residing in North American deserts of Mexico and the United States are "among the most drought-adapted annual legumes on earth." These communities value these beans for their low water use, flavor and nutritional value (Nabhan 2013: 48), and they can help to build resilience against shifts in agricultural conditions under climate change. However, it is difficult to know whether more people are growing these varieties and saving their seeds. More comprehensive research is needed to assess the agrobiodiversity conserved through seed exchange networks and evaluate their impact on food system resilience. As one staff member at SSE explained in its early years (Whealy and Adellman 1986), the seed exchange network has been successful to make people actually want to save seeds, which is an important aspect of sustainability of agrobiodiversity.

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