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Civic seeds: new institutions for seed systems and communities—a 2016 survey of California seed libraries

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Abstract Seed libraries (SLs) are institutions that support the creation of semi-formal seed systems, but are often intended to address larger issues that are part of the "food movement" in the global north. Over 100 SLs are reported present in California. I describe a functional framework for studying and comparing seed systems, and use that to investigate the social and biological characteristics of California SLs in 2016 and how they are contributing to alternative seed systems based on interviews with 45 SL managers. At a minimum, SLs function as new seed distribution institutions founded and overseen by dedicated, values-driven individuals and groups with goals including education, seed access, local adaptation, biodiversity conservation, community-building, and human health. Annually about 4776 people borrow seeds from, and 238 people return seeds to the SLs in this study, that operate through over 17,000 hours of work/year. These SLs distribute approximately 6456 packets of seed annually, mostly of commercial seeds from small seed companies, but some SLs emphasize local and culturally meaningful seeds. The significance of a 6% seed return rate depends on SL goals and can be investigated once appropriate indicators for those goals are identified and documented. Beyond distribution, the seed system functions accomplished by SLs differ, and all can have consequences for the processes shaping the diversity and adaptation of their crops. The SLs engaged in seed system functions beyond distribution are new forms of socially-motivated community science, poised to develop biological and social innovations reflecting their values and interests.

Keywords California · Community science · Food gardens · Seed library · Seed system · Urban agriculture

Abbreviations

GMO	Genetically modified organism
NA	Not appropriate
SL	Seed library
SSE	Seed Savers Exchange
US	United States of America

Introduction

Agricultural seed systems are integrated social and biological systems we use to supply seeds for the food and fiber plants we grow. The interplay between social and biological factors defines the selection pressures agricultural plants experience that result in evolution, and is the basis of crop domestication (Harlan 1992), and ongoing adaptation.

Much agriculture in the "global south" includes seed systems developed by local farming and gardening communities to serve their small-scale agriculture. Conventional, corporate seed systems serve large-scale and industrialized agriculture world wide, and dominate in the "global north." Over the last several decades, alternative agricultural seed systems have been created based on values that directly contrast with those of industrial agriculture. One relatively recent alternative is small, local "seed libraries" (SLs).

Seed libraries are growing rapidly especially in the global north, including the US, where the number of SLs has increased from one established in Berkeley, CA in 1999, to

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900 self-identified SLs as of November 2016 (Seed Library Network 2016). As part of community-based alternatives to conventional seed systems, SLs typically offer seeds to "borrowers," following the model of book lending, although the expectations for returning seeds varies.

The rapid rise in the number of SLs suggests that these new institutions reflect compelling interests and concerns among some members of the public.[1] Mission statements on prominent California SL websites typically describe goals beyond recreation, including "meeting the challenge of climate change…(through) a new alliance of seed stewards to turn our seeds into the most resilient and abundant food supply in our uncertain world,"[2] and "increasing community capacity to feed itself wholesome food…. (the SL) celebrates biodiversity….nurtures locally-adapted plant varieties, and fosters community resilience, self-reliance."[3]

This paper analyzes the findings of a 2016 survey of SLs in California, and provides a benchmark for future research on SLs. While a recent overview of alternative seed systems in the US included SLs (Helicke 2015), the work reported here is to my knowledge the first systematic, quantitative investigation of the social and biological characteristics of SLs anywhere. I analyze California SLs as part of alternative agricultural seed systems, asking how their characteristics and functions vary across SLs, reflect SL values, and could impact the diversity and adaptation of crops. I also consider how some SLs may be examples of novel, community-based research.

The alternative food movement

While the recent increase in SLs in the US has been rapid, it builds on the larger alternative "food movement" (Pollan 2010), which has grown in opposition to the dominant food systems controlled by large, multinational corporations. The most prominent component of the alternative for decades was "organic" agriculture, although it has been increasingly co-opted by industrial growers (Guthman 2004). The alternative food system focus has shifted to localization, for a variety of reasons (Martinez et al. 2010). Localization includes household and community food gardening (Grewal and Grewal 2012), which SLs are almost always associated with (Conner 2015), and which increased 17% in the US between 2008 and 2013, with 42 million households food gardening in 2013 (NGA 2014).

Alternatives to the dominant, corporate seed systems are also a focus of localization. Concerns regarding loss of varietal diversity in US seed systems grew after the 1969–1970 southern corn leaf blight epidemic, which a National Academy report attributed to narrow genetic diversity in maize, while warning of the threat of diversity loss in all crops (NRC 1972). A 1983 study by the nongovernmental organization RAFI (Rural Advancement Fund International) (Fowler and Mooney 1990) compared horticultural varieties present in 1983 in the US national "seed" bank (now called the Plant and Animal Genetic Resources Preservation Unit), with varieties listed 80 years earlier by the USDA, based on a 1903 review of major US seed catalogs. RAFI found a reduction or "extinction" of 97% over that period, measured as named varieties on the 1903 list that were not in the seed bank in 1983. In 2011 this finding was brought back into wide public view, along with an arresting visual in the *National Geographic* (Siebert 2011), which was, however, challenged using other data (Heald and Chapman 2012).

The 1983 study is important because it was the first compilation of data on varietal diversity in garden crop seeds. Yet conclusions about trends in crop genetic diversity like these are difficult to make because estimates of numbers for both the beginning and end of the study period, and in the recent re-evaluation (Heald and Chapman 2012), are based on lists of named varieties that biological studies have shown to be very incomplete indicators of diversity in both industrial (Bonneuil et al. 2012), and traditional agriculture (Soleri et al. 2013). Still, the increased awareness of possible loss of crop genetic diversity that these studies stimulated may have contributed to two waves of grassroots interest in alternative seed systems that are described below: small seed companies and organizations in the late twentieth century, and SLs in the early twenty-first century.

Ongoing consolidation in the industrial seed system may have also stimulated interest in alternative seed systems. A study of commodity crop seeds (e.g., maize, soy, cotton, rape) found substantial horizontal consolidation and vertical integration, resulting in greater domination by a few corporations, and rising genetic homogenization due to corporate structure and cross-licensing of widely used traits (Howard 2009). Consolidation has spread from major field crops to horticultural crops. For example, Seminis®, the largest horticultural seed firm in the world (owned by Monsanto since 2005), was estimated by one of its own researchers in 2008 to control 75% of the US field tomato seed market (Dillon 2008). Seminis® now offers seeds for home gardens as well. Corporate consolidation and genetic homogenization are among the reasons industrial agriculture and seed systems have been seen as neglecting the values and goals of localization (Helicke 2015), inspiring the search for alternatives.

[1] Here "institution" refers to an organized, shared method of interaction in relation to a particular process or resource, that defines the constraints and opportunities available to the participants (McGinnis 2011; Soleri et al. n.d.).

[2] Seed Library of Los Angeles. http://slola.org. Accessed 9 Aug 2017.

[3] Richmond Grows Seed Lending Library. http://www.richmondgrowsseeds.org. Accessed 9 Aug 2017.

Recently the food movement has included alternative agriculture and seed systems initiatives of a number of public sector and non-profit organizations (e.g., Hubbard and Zystro 2016; Tracy and Sligh 2014). In part, this is in response to the nature of the institutions and restrictions associated with transgenic (also called "GMO," genetically modified organism) crop seed. For example, increasingly only transgenic seed with strong intellectual property rights and contractual protections is available for commodity field crops such as maize and soybean, due to corporate consolidation and prioritizing profit-making (Howard 2015).

A community-based alternative initiative is the establishment of local community seed banks worldwide (Vernooy et al. 2015), for example in Oaxaca, Mexico where they are governed by, and operated for, farming communities (Aragón-Cuevas 2015). These are alternatives to the formal, industrial seed systems that many gardeners and small-scale farmers have found economically, agroecologically, or socioculturally inappropriate (e.g., Sin maíz no hay país 2007).

The trends in alternative food, agriculture and seed systems described above are present in California. For example, interest in localization has included establishment of local food hubs that make it possible for small farmers and local institutions like schools and universities to work together (Cleveland et al. 2014); a "Good Food Purchasing Pledge" includes guidelines for buying local, and has been adopted by the City of Los Angeles, and the LA Unified School District (LAFPC 2014); an active "California Regional Seed System" chapter of the Organic Seed Alliance's farmer-plant breeder collaboration to develop locally appropriate seed for organic production; the passage in six California counties (Humboldt, Marin, Mendocino, Santa Cruz, Sonoma, and Trinity) of measures for GMO-free agriculture; and leading a legal protections campaign for seed libraries nationwide (SELC 2017), including crafting and helping pass a California non-commercial seed sharing law (AB-1810 California Seed Law 2016).

However, it is important to note that food movement initiatives are not necessarily alternative in all senses. In the industrial world they may not include some groups, for example support for small-scale, or organic farmers has often omitted, or even undermined, long-time African and Native American farmers (e.g., Daniel 2013). Local, alternative sources of healthy produce, including community supported agriculture and farmers markets often do not serve diverse populations, or at least do not make them feel welcome (Alkon and McCullen 2011; Guthman 2008).

The alternatives described above are all part of the "food movement" that "coalesces around the recognition that today's food and farming economy is 'unsustainable'—that it can't go on in its current form much longer without courting a breakdown of some kind" (Pollan 2010). This is the context in which SLs in the US have been established and grown as part of alternative, community seed systems.

A functional seed system framework for investigating seed libraries

The functional seed system framework outlined below is a heuristic tool for describing and investigating seed systems, and contrasts with previous frameworks, which have focused on traditional agricultural systems (Jarvis et al. 2011; Pautasso 2015), or on those and European farming systems (Thomas et al. 2011). This framework provides an overview of seed systems that includes both social and biological elements, starts with seed system functions, and is useful for comparing different seed systems, and parts of those systems, like SLs.

Research on agricultural seed systems has identified a range in *scale* between informal, small-scale seed systems that are primarily local, and formal, large-scale, non-local, seed systems (Almekinders et al. 1994) (see Table 1). This classification is necessarily simplified because seed systems often comprise institutions and other components from a range of scales. For example, research on the informal maize seed systems in two communities in Oaxaca, Mexico found that, although all households reported saving their own seed on-farm, 85% had also gotten seed off-farm in the previous 10 years, including 27% from local markets and 15% from agricultural stores selling seed from the formal system (Soleri et al. 2005). The same study found examples of maize seed movement in informal systems from Angola to Cuba, the US to Guatemala, and Guatemala to Mexico. These examples demonstrate that informal seed systems are rarely—if ever—closed, may include seed that is from the formal system, and they may not be geographically "local," findings confirmed by other studies (e.g., Heraty and Ellstrand 2016; Louette et al. 1997).

The six basic *functions* of an agricultural seed system (conservation, improvement, multiplication, distribution, production, consumption) are present throughout the range in scale just described (see Table 1). In informal systems most functions occur locally within a household, or households, based on personal social networks (e.g., Calvet-Mir et al. 2012; Ellen and Platten 2011). In formal systems the same six functions mostly occur separately, in specialized institutions, and use commercial networks that frequently operate at national and multinational scales, as a result of horizontal and vertical integration (Howard 2009, 2015) (see Fig. 1). Most seed systems, including formal ones, leave production and consumption functions to gardeners, farmers, and consumers although at smaller scales production may be a source of seeds, and consumption will influence decisions about what material to conserve.

Table 1 Variables in the functional seed system framework

Range of scale	
Small, informal	Individual or multiple households directly linked through personal social networks
Large, formal	National and multinational, linked through commercial transactions and political affiliations
Functions	
Conservation	Preservation of propagules like seeds, or genes for future use, including the following year
Improvement	Selection by people and/or environments to maintain or change crops to better meet people's needs and preferences
Multiplication	Growing sufficient seeds to meet producers' needs
Distribution	The way in which seeds are made available
Production	Growing the plant or crop for its intended uses, may include processing if appropriate
Consumption	Preparing and eating the food
Components	
Institutions	How people organize to accomplish functions, express values
Practices	Techniques used to accomplish functions; e.g., hybridization, transgenesis, mass selection, participatory varietal selection, cold storage, in situ conservation, etc
Seeds	Material managed by seed system institutions
Knowledge and values	Understanding of how seed, food, and agriculture systems work, and beliefs about how they should work and what they should do
Processes shaping crop diversity	
Gene flow	Movement and establishment of genetic material (alleles, pollen, seeds, populations, species) in new populations or areas
Selection	Identification based on phenotype of individual plants that will contribute their progeny to the next generation
Genetic drift	Random reduction in population size, often resulting in a loss of genetic diversity
Mutation	Permanent change in genetic material, the ultimate source of genetic diversity

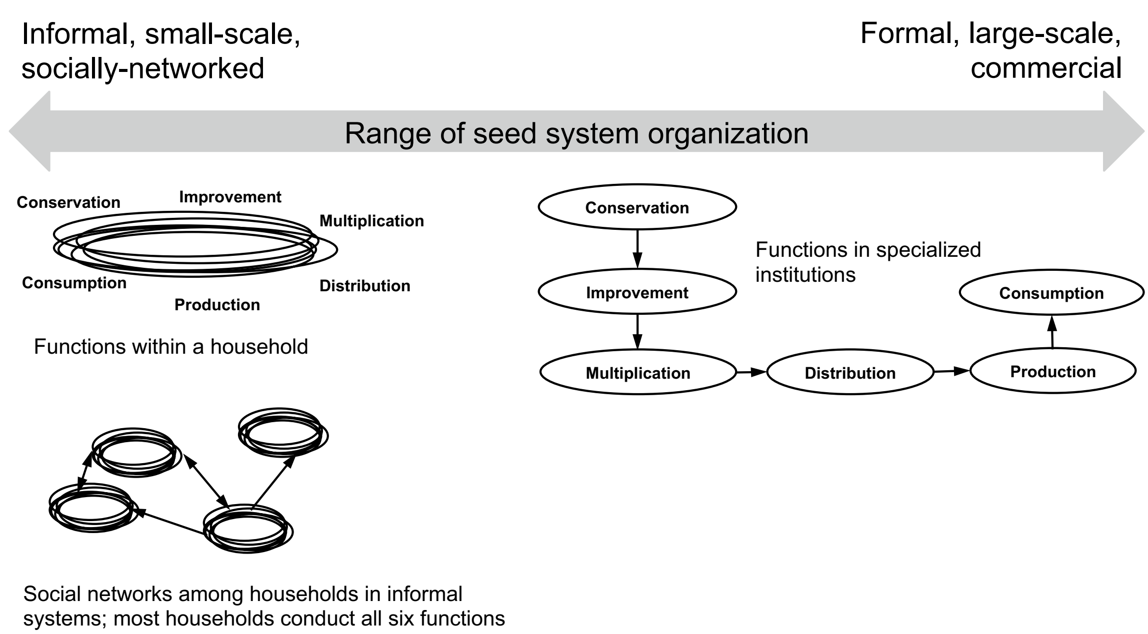

Fig. 1 The range of seed system organization

Others refer broadly to informal seed systems as "farmer seed networks" (Coomes et al. 2015), intentionally avoiding what they see as negative connotations of "informal" as "an absence of or diminished role of social rules and norms that govern circulation." However, I use "informal" to indicate a predominance of direct, personal, social networks that distinguish these kinds of seed systems.

All seed systems include these same functions, but in this framework the manner in which seed system functions are accomplished depends on four *components*: the *institutions* people create for the seed system; the *practices* used to accomplish the functions, which affect the environments that seeds and plants experience; the *seeds* or other propagules and the plants grown from them, including their mating system, genotype and phenotype; and the *knowledge and values* of the people in the seed system, which have a large influence on the other three components. For example, recent university-based research on alternative dry bean farming systems in western Washington state has included development or support for components that are different than those used in conventional bean production (Brouwer et al. 2016): *institutions* for improvement including participatory plant breeding partnerships between farmers, plant breeders and chefs; *practices* including the use of small-scale harvesting equipment, selection on-farm, and accessing seeds outside of the formal system; *seeds*—"heirlooms" grown locally for 20–130 years; and *knowledge and values*, such as those of farmers and chefs, and small-scale producers, and including the historical significance and culinary quality of the varieties.

The way components are used to accomplish agricultural seed system functions affects the *processes* that shape crop diversity, and are common to all forms of life (e.g., Hedrick 2005) (see Table 1): gene flow, selection, genetic drift, and mutation, although mutation is beyond the control of gardeners and farmers. This diversity defines the potential for adaptation to local interests, needs, and changing conditions. For example, studies of in situ and ex situ conservation of maize varieties over 40 years (Soleri and Smith 1995) and rice varieties over 17 years (Tin et al. 2001) both found that these different conservation practices affected processes differently, and were therefore associated with differences in crop phenology and other characteristics. That is, in each case selection, and perhaps gene flow and drift were not the same in in vs. ex situ conservation. In each case the differences were interpreted as making the in situ populations better adapted to farmers' needs and on-farm conditions.

The informal and formal seed systems described above bookend the many variations that exist worldwide. Over the last 40 years in the US many new institutions were created to support alternatives to conventional, industrial systems, driven by values such as conserving crop diversity, and independence from multinational seed companies serving industrial agriculture. Many of these institutions offer gardeners and farmers the possibility of practices that are different than those available in larger, formal systems. For example, when alternative seed system institutions use open-pollinated varieties and exclude contractual or intellectual property restrictions, gardeners and farmers can save seed.

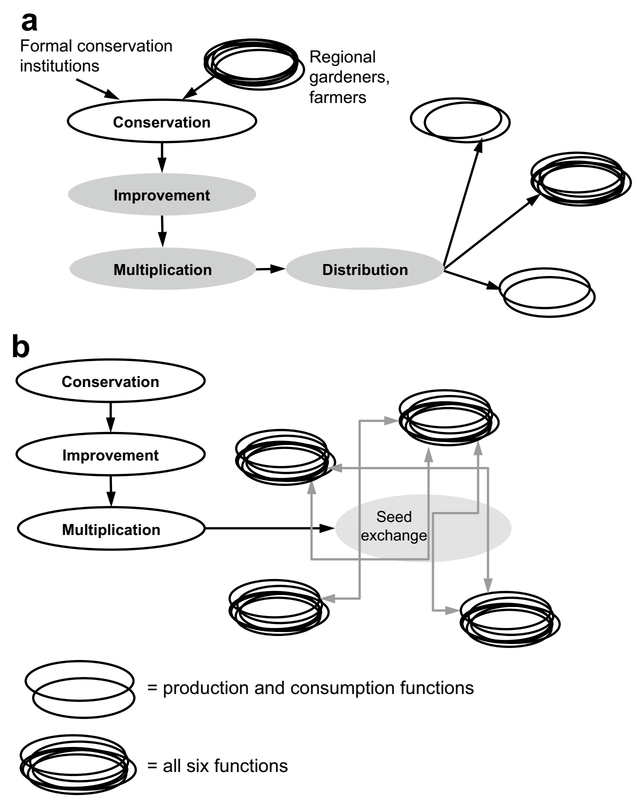

Fig. 2 Examples of alternative seed system institutions that obtain germplasm from different sources; shading indicates functions they perform. **a** Regional seed companies. **b** Seed exchanges

An example of an alternative formal seed system institution is the Open Source Seed Initiative (OSSI),[4] through which farmers, gardeners, and public and private plant breeders can share crop genetic resources, and sell the varieties they develop or save seed from, with all of these materials remaining non-proprietary, that is, part of the "protected commons" based on the OSSI pledge (Luby et al. 2016). Open Source Seeds[5] is a similar, but license-based program now underway in Germany (Laursen 2017). Other alternative institutions include regional, commercial seed companies that obtain germplasm from diverse sources including farmers and formal conservation institutions, and perform the functions of improvement (plant breeding), multiplication and distribution, for specific markets (e.g., Territorial Seed, founded 1979; High Mowing Organic Seeds, founded 1996) (see Fig. 2a). Another example is the mission-driven, non-profit seed company focused on conservation, multiplication, and distribution of "heirloom" and other traditional

[4] Open Source Seed Initiative. http://osseeds.org/. Accessed 9 Aug 2017.

[5] Open Source Seeds. http://www.opensourceseeds.org/en. Accessed 18 Aug 2017.

crop varieties, whose improvement function may be maintenance selection to minimize genetic change (e.g., Seed Savers Exchange (SSE), founded 1975; Native Seeds/SEARCH, founded 1983).

I define semi-formal seed systems as alternative, non-commercial seed sharing through an institution that extends the system beyond personal social networks, with free (or trade-based) distribution a qualifying function. Like other seed systems, semi-formal ones take different forms and use or create different institutions to accomplish the seed system functions. Examples of semi-formal seed system institutions include SLs and seed exchanges or "swaps"— events where gardeners, farmers and others bring seeds to exchange, and obtain seeds themselves, typically free of charge or traded in kind (e.g., Campbell 2012) (see Fig. 2b). In addition to distribution, some SLs perform one or more of the other seed system functions, as shown below for California.

Methods

Using this framework, I created an interview-based survey to investigate SLs as seed system institutions. I compiled a list of all SLs in California using the self-reported list maintained on the "Sister Libraries" page of the US-based Seed Libraries Network as of January 10 2016 (n = 98).[6] Between February and June of 2016, nine additional libraries or other institutions supporting semi-formal seed systems (hereafter all referred to as seed libraries, SLs) were added by the network, and I identified three more for a total of 110. Contact information was not available for 26 SLs. Of the 84 SLs I tried to contact, 36 did not respond to three or more attempts to reach them by email, and when a number was available, also by telephone. The primary person responsible (hereafter SL "manager") for the remaining 48 SLs was interviewed, and 45 interviews were completed. For all SLs interviewed the manager was emailed an explanation of the research and a copy of the interview instrument. Approval of the University of California, Santa Barbara institutional review board was obtained, and interviews were conducted by telephone or Skype after interviewees received and signed a consent form. Interviews were recorded unless permission was not granted for doing so (n = 2).

The interview schedule (available on request) had 50 questions, some of which were multi-part, including yes/no, multiple choice, short answer and open-ended formats. Interviewees were asked the goal of their SL as an open-ended question, with key words or phrases manually tallied from interview recordings to quantify goals across the sample (see Table 2 and its footnote). The interview was designed to elicit responses about four main topics: the first three of these concerned social characteristics of SLs—who manages them, the SL's values, and where and how they operate. The fourth question was about SL biological characteristics—their seeds and how those seeds move. The interview took 20–60 min to complete. Everyone interviewed was provided with the completed data sheet for their own interview, and access to an anonymized online spreadsheet with summaries of the quantitative data from all interviews.

Many SLs do not maintain records of patrons, seeds and transactions. However, some of these SLs made estimates based on seed orders, number of events and attendees at each, observations of daily SL traffic, and other means. When SL managers felt confident that their estimates could characterize their SL accurately, those estimates were included, and methods for making them noted. If they did not feel confident, or had no basis on which to make such estimates, no data were included for that variable. Thus, although the entire sample was 45, sample size varies across questions as indicated in the data tables.

Here I report descriptive statistics and some *t tests* ($p < 0.05$) calculated using LibreCalc, version 5.2.6.2, and other summaries of responses from my interviews with SL managers.

Findings and discussion

When working with the Pueblo of Zuni's Sustainable Agriculture Project in western New Mexico, USA in the mid 1990s (Cleveland et al. 1993; Soleri and Bowannie Jr. 1994), one activity already being explored, and that we discussed with farmers, was a community seed bank. But the logistics involved were not practical at the time, so the focus shifted to a project-managed "seed exchange network" of and for the Zuni community. A Zuni farmer and project colleague pointed out that due to longstanding disagreements some families, including his own, did not interact with certain other families, and they would never share seeds with each other. But, he went on to say, he would be willing to share seeds with the project seed exchange, and wouldn't mind which other tribal member got those seeds through the exchange. And besides, he added, he would like to have access to seeds from some of those other families as well. Our colleague was describing how institutions like a project-managed seed exchange can expand non-commercial seed sharing from a small-scale, informal seed system to a semi-formal one that extends beyond personal social networks, so that even people whose personal networks do not overlap can benefit from, and contribute to, seed sharing. This is a role played by the SLs and similar institutions supporting alternative, semi-formal seed systems in California that were

[6] Seed Libraries. 2017. Sister libraries. http://seedlibraries.weebly.com/sister-libraries.html. Accessed 13 Aug 2017.

the focus of this research. However, as described below, they accomplish this in different ways, and with a diversity of goals.

Management of California SLs

Seed libraries are relatively new in California, with most SL managers also being the SL founders, who defined the form of the institution, its practices, the values on which it is based, and the seeds chosen. Most SL managers were longtime California residents with gardening experience and post secondary education (ESM Table S1).[7] They were overwhelmingly Caucasian (80%), female (73%), and middle aged (mean 49, median 51 years old), very similar to the profile of public librarians nationally in a self-reported survey: 87% Caucasian, 81% female, and 55% ≥ 45 years old, with a median age of 51 (American Library Association 2016). This similarity is likely because 67% of SLs were located in public libraries, and 44% of SL interviewees were library employees, including a diversity of titles from head librarian to part time technician.

However, some diversity can be found among SL managers. For example, in two small California towns, white males over 69 years old, each of whom are longtime plant and garden enthusiasts have developed their own seed collections, which they make available monthly, along with advice and information, to community members through public meetings announced in local newspapers. One of these men also solicits commercial seed donations, and they both offer varieties with a long history in their areas. Employees in three different Native American Tribal Environmental Departments, all of them under 37 years old, have started or are managing SLs in conjunction with tribal community gardens and other programs, and make important traditional and native plants available to their communities. In downtown Los Angeles a middle aged, male, African American cultural change agent and gardener has provided seeds, starts, and education to approximately ten elementary schools, and for others who come to the garden center of his non-profit organization to learn more about its publicized work. All of these examples differ substantially from the most common, public library-based SLs and SL managers found in this research. Using the framework and looking for institutions that make semi-formal seed systems possible in their communities can help identify institutions that do not call themselves SLs but fill that role, as was true of two of the examples described above.

In addition to their association with public libraries, there are other likely reasons for the relatively homogeneous demographics of SL managers, including institutional racism. As the African American cultural change agent in Los Angeles explained: "Seeds are very important, every thing, including us, started from a seed….[but]…seeds are not the problem, seeds are easy. The problem is people don't give a **** about them, that's the problem, it ain't got nothing to do with seeds. It's got everything to do with culture. It's got everything to do with understanding. It's got everything to do with what people have been shown, and it's that this life has been designed for them. The fact that there is a disparity in the educational system has been designed for them. The fact that they can get alcohol faster than they can get an organic apple, that's designed for them. All this is by design, it's not happenstance." Distinguishing between essential resources (e.g., seeds) vs. the fundamental problems (e.g., structural racism) that constrain lives is a significant insight that rejects a hierarchy of needs interpretation of the lack of diversity in SLs, as has also been demonstrated in studies of environmentalism (Mohai and Bryant 1998; Whittaker et al. 2005). This and other SL managers' work embody a rejection of that interpretation, by valuing seeds, gardens, health and community as part of a response to racism. Observations of other food movement alternatives such as farmers markets and community supported agriculture, have also questioned attributing the lack of engagement by communities of color to a lack of interest, instead documenting "minor exclusionary practices," and their underlying assumptions as the causes (Alkon and McCullen 2011; Guthman 2008; Slocum 2007).

The values of California seed libraries

I used California SLs' declared goals, which centered on seven topics, and the types of seeds they distributed, as representing their values (Table 2). These include personal, biological, social and political goals, with education the most common, especially about the seed and food systems, and the environment.

Many SL managers were passionate about SLs and the values they see SLs representing. For some, these include the spiritual: a SL manager in a small, northern California town said "some kind of religious and philosophical motivation is important, practical motivation is also an important factor, all are highly advantageous in seed saving. You love thy neighbor if you are doing seed sharing." For others the values are related to physical and mental health, environmentalism, and/or power. The manager of one Oakland SL remarked: "This [the SL] is important…. The SL is a part of extending our services to the community. Growing food is something you can do, it puts you in touch with the earth, even when growing in containers inside. It is another rung in the mental health ladder; caring for something is positive, and also offers people some control in their lives." Others

[7] Electronic Supplementary Material, files associated with this paper that are available on the Springer website.

Table 2 The values of California seed libraries expressed through their goals and types of seed distributed (n = 45)

Characteristic	Percent of seed libraries		
	Stated	Not stated	No explicit policy
Primary goal(s) of seed library[a]			
Education	73%	27%	NA
Seed access	53%	47%	NA
Seed adaptation	33%	67%	NA
Preserving/enhancing biodiversity	16%	84%	NA
Health/food sovereignty	40%	60%	NA
Community, culture of sharing	36%	64%	NA
Resistance to corporate control in seed, agriculture, or food system	18%	82%	NA
	Yes	No	No explicit policy
Uses the "Safe Seed Pledge"[b]	23%	77%	NA
Choice of seed types			
Would use transgenic seed	2%	84%	14%
Would use hybrid seed	2%	49%	49%
Only use heirloom seeds	41%	2%	57%
Only use organically grown seed	28%	2%	70%

Keywords and phrases used to identify seed library goal in response to open question: "What is the primary goal of the seed library?" are as follows:

Education = Education, learning, teach, train, self-education, empower to plant and grow, knowledge, nurture, workshops, classes

Seed access = Accessible, available, provide seeds, affordable, responding to poverty

Seed adaptation = Adaptation, local varieties, saved/selected here, right for here

Preserve/enhance biodiversity = Biodiversity, bring back lost varieties, keep "heirlooms" going, against reducing the number of seeds available

Food/health sovereignty = Health, healthy, nutrition, food independence/security/sovereignty, eating fresh, know where food comes from

Community, culture of sharing = Community, culture of sharing, community building

Resistance to corporate control in seed, agriculture, or food system = No "GMOs," no hybrids, no processed, only "heirlooms," only open pollinated varieties, clean seeds and food, rebellion against what's happened in the seed industry

NA, not appropriate

[a]Many reported more than one

[b]http://www.councilforresponsiblegenetics.org/Projects/CurrentProject.aspx?projectId=17

emphasized that seeds are the basis for a better food system and society. One Bay area SL manager explained, "Seed is a foundational component for sustainability and resilience, including for food security, building community, addressing climate change, (and) preserving biodiversity."

The values of SLs are also implicit in the types of seeds they offer. A few SLs offer any seeds they can obtain, focusing entirely on the distribution function for greater seed access. But most have criteria for choosing seeds that reflect values about the environment, health, power and equity. For example, seeking culturally significant species and varieties, or ones with a long local history, not knowingly offering hybrid seed, or offering only organically produced seed of open pollinated, "heirloom" varieties. While many SLs preferred to use only organically grown seeds, this is not an enforced policy for the majority. Transgenic crops continue to raise ethical issues in the US (e.g., Frewer et al. 2013), and although transgenic seed sales do not target gardeners in the US, varieties of some species of horticultural field crops that gardeners might hypothetically grow are approved for cultivation in the US, including: apple, beet, papaya, plum, potato, radicchio, summer squash, sweet corn, and tomato (USDA APHIS 2017). Thus as a value statement about ethics, nature or control of seed systems, or concern for transgenic gene flow, the majority of SLs said they would not offer transgenic seeds; some have signed the "Safe Seed Pledge" (see Table 2),[8] and eight are located in California counties with laws prohibiting the planting of transgenic seeds.

Using the functional framework we can see how SLs are playing different roles in semi-formal seed systems, reflecting their values and capacities. By definition, all SLs are at least fulfilling the distribution function (see Fig. 3a), making seeds more accessible, either as a goal in itself, or as a step toward other goals such as education, better health or food sovereignty. In these cases the conservation, improvement and multiplication of SL seeds are most often conducted by institutions that are part of more formal seed systems, such as regional or specialty seed companies. Seed distribution can also be the first step in supporting a culture of sharing, especially for SLs based in public libraries, 69% (11/16) of those declaring this as a primary goal.

Seed libraries make seed accessible because they have few requirements for seed borrowing. All SLs in this study offer seeds for free, although two require a small lifetime membership fee to join the parent organization—$20 for one, $10 for the other—to support the SLs' infrastructure and educational activities. Two other SLs require completion of a registration form before seeds may be borrowed. Only 10% (3/30) of SLs located in public libraries require a library card to use the SL. All together, 67% of California SLs in this study have no pre-requisites for borrowing seeds,

[8] Developed in 1999 by the non-profit Council for Responsible Genetics, the pledge declares the signatory "does not knowingly buy, sell or trade genetically engineered seeds or plants," (http://www.councilforresponsiblegenetics.org).

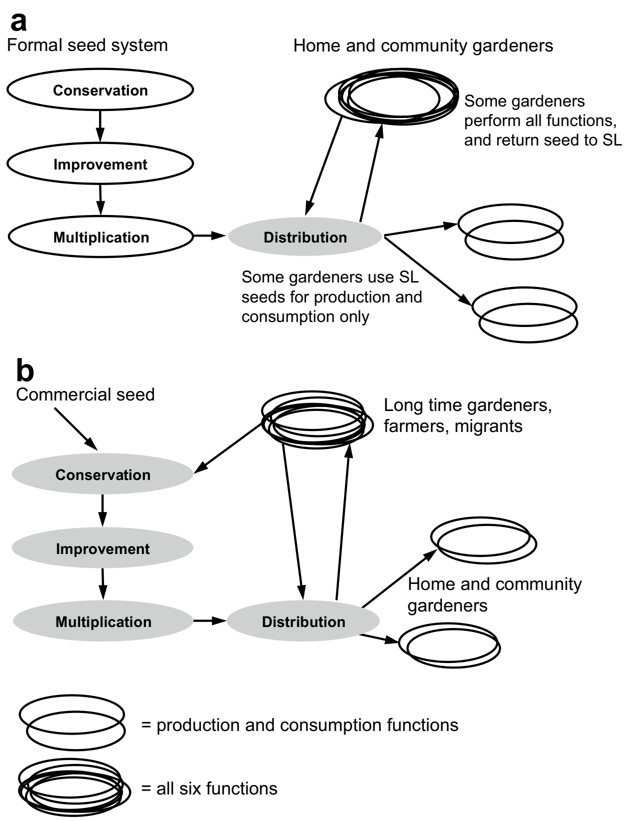

Fig. 3 Seed libraries as alternative institutions for one or more functions in semi-formal seed systems. Shading indicates functions accomplished by SLs. **a** Seed libraries as alternative distribution sources. **b** Seed libraries accomplishing multiple seed system functions

and many others ask borrowers to complete paperwork, but never require it. Collecting information about borrowers and seeds is time consuming and most SLs do not have staff for this. Some managers pointed out that requiring paperwork is a deterrent for certain borrowers, undermining the goal of greater seed access, so they do not ask. Seven SL managers noted their commitment to underserved populations that might be reluctant to borrow seeds if paperwork was required. Instead, these managers described encouraging broad engagement by providing free seeds, education, and seeking out hard-to-find varieties with cultural significance for their borrowers.

In another expression of their commitment to accessible, alternative seed systems, some SL managers in California and elsewhere, and their allies, have worked for legislative changes supporting SLs. In 2014 a Pennsylvania SL was closed by that state's Department of Agriculture for violating Pennsylvania's seed law designed to protect commercial seed quality (SELC 2014). At least two SLs I contacted that are no longer operating cited the Pennsylvania case as the reason they closed, and it represented a perceived threat to their SL for some SL managers. The SL activists responded to the 2014 closure by helping craft new laws in California, Minnesota, Nebraska and Illinois that protect non-commercial seed sharing from regulatory requirements for commercial seed (SELC 2017). The Association of American Seed Control Officials (AASCO), seed professionals in the US and Canada, developed the Recommended Uniform State Seed Law as a template to support consistency across state seed laws, and conformity with national laws. A statement adopted in July 2016 by AASCO recognizes "non-commercial seed sharing" and its exemption from state and national seed regulations, making it easier for more states to recognize SLs' legality in the future (SELC 2017).

Some California SLs have goals of local adaptation, or preserving/enhancing biodiversity (including culturally appropriate species or varieties), and are striving for an expanded role, including in some cases becoming completely self-provisioning for seeds. This means the seed system functions of conservation, improvement, and multiplication, are also important for these SLs, so they encourage borrowers growing seeds locally to return them (see Fig. 3b). For some of those SLs conservation includes acquiring and maintaining materials for their collections from longtime gardeners, aging farmers on "Granny farms," and migrants, as well as plant breeders and conservationists in the formal system. Rare material may be given special attention, for example by recruiting experienced gardeners to multiply seed before making it available for public borrowing.

All of the stated SL goals can impact the diversity shaping processes of gene flow, selection and genetic drift. Seed libraries with the explicit goal of adaptation, or managers with a particular interest in seed saving, plant biology or breeding, are using these processes most directly, and sometimes intentionally (see Table 3). For example, when local adaptation is the goal, the improvement function focuses on selection for adaptation, instead of maintenance selection to preserve the varieties unchanged. In two cases SLs only distribute seed that has been locally grown for one or more generations. One SL asks seed returners about isolation practices used (which control gene flow) and whether any intentional selection was performed. To help recognize small population size in seed returns due to genetic drift or selection, nine SLs ask people returning seeds to indicate the number of plants the seeds came from, and some SLs are creating guidelines for when to pool seeds of the same variety. However, currently 87% (27/31) stated they would not pool seeds of a variety grown in the same year by different gardeners, and 88% (30/34) would not pool seeds of the same variety grown in different years, out of concern for variable quality in returned seed lots, the possibility that the varieties are not in fact the same, or wanting to maintain any site or year specific adaptation that may have been selected for. To overcome small population sizes, some SLs

Table 3 Three diversity shaping processes in the context of seed libraries

Process	For seed library		Examples of seed library practice
	Potential problem	Potential benefit	
Gene flow	Lack of purity, loss of varietal identity	Bring new or local cultural, species, varietal, genetic diversity into seed library collection	To avoid: Eliminate outcrossing species Do not use returned seeds except from predominantly selfing species Gardener skill influences fate of returned seeds To encourage: Intentional mixing and selection (e.g., favas) Hand pollination (e.g. squash) Obtain seed stock from longtime farmers, gardeners, migrants, conservation organizations, USDA
Selection	Small population size, loss of "insurance" diversity (Jarvis et al. 2008)	Adaptation, distinct desirable characteristics	To avoid: Avoid outcrossing species vulnerable to inbreeding depression Pool populations of same variety Do not use returned seed To encourage: Allow environmental selection to support adaptation Form regional adaptation groups for seed growing and sharing Only managers and specialists conduct selection (e.g., quinoa phenology classes) Train specialists to do selection
Genetic drift	Small population size, loss of diversity, especially rare alleles and genotypes	NA	To avoid: Do not use returned seed Pool populations of same variety Enlist farmers to help grow out larger populations Form regional adaptation groups for seed growing and sharing

NA, not appropriate; USDA, US Department of Agriculture

are establishing grow out programs, or partnering with local farmers to grow large populations for seed.

Regardless of their goals, many SLs try to avoid negative consequences of diversity shaping processes by referring users to free educational materials, especially online sources.[9] These materials include information such as standard isolation distances to avoid cross pollination, and minimum population sizes to avoid harmful loss of diversity due to selection or genetic drift. They also give advice on avoiding inbreeding depression (reduced fitness, especially from expression of deleterious alleles due to mating of plants with similar genotypes), a possible consequence of selection or genetic drift, particularly in outcrossing species that are especially sensitive to this.

California seed library locations and operating practices

The SLs participating in this study are from 22 counties across California (see Fig. 4), and from a range of community sizes, although the majority are in large urban areas (see

[9] Seed Savers Exchange educational resources (http://www.seedsavers.org/learn); Organic Seed Alliance's publications (https://seedalliance.org/publications/seed-saving-guide-gardeners-farmers/), including their "A seed saving guide for gardeners and farmers," that contains the original seed saving chart that SSE's is based on; other sources, including some listed on Richmond Grows Seed Lending Library's seed saving page (http://www.richmondgrowsseeds.org/seed-saving.html). All accessed 9 Aug 2017.

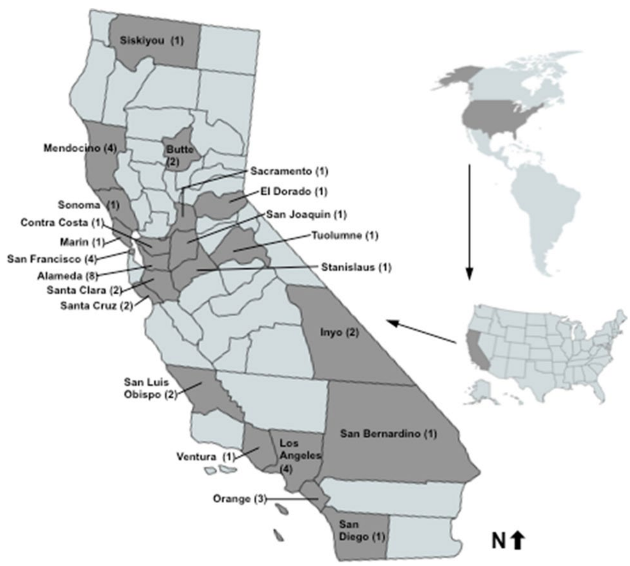

Fig. 4 California counties and number of seed libraries in each included in this study

ESM Table S2). This may be because 95% of California's population lives in urban areas, and the strong growth in urban food gardening nationwide (NGA 2014). Seed libraries occur in communities of different socioeconomic status, with community[10] poverty rates (percent of the population living below the federal poverty guideline)[11] from less than 4% to more than 41%. Forty-seven percentage of SLs are located in zip codes with higher poverty rates than the larger community in which they are located, and the majority of SLs in this study are in communities with poverty rates higher than the national mean of 13.5% (USCB 2017). A slight majority (53%) of California SLs in this study are in predominantly white communities, even though the California population as a whole is only 39% white (USCB 2017). However, physical location may not always define who SLs serve; several urban southern California SLs, and one in a small town in the north of the state, reported having people travel from other communities to borrow their seeds.

Among SLs in this study the mean founding year was 2012, but those housed in community centers, non-profits, schools and other non-library locations are significantly older than SLs in public libraries. For example, one SL (not registered on the Sister Libraries site) operating part time out of a community center and the manager's home started in 1996 in Northern California; another in the San Francisco Bay area was started in 1999 (Table 4).

Public library-based SLs are open significantly more hours than SLs located elsewhere. Most public library SLs provide open access to seeds during library hours using a self-serve model that does not require interaction with SL personnel. Tribal-based SLs are also open many hours because they are housed in tribal program offices, though for two of these, the appropriate persons must be present to assist SL users. Other SLs are housed in parent organizations and accessible when those are open, or are available at scheduled meetings or events. Three of these require interaction between borrowers and SL workers to ascertain borrowers' gardening experience and goals before lending seeds. In another SL in a very small rural community, borrowers receive seeds directly from the SL manager, who is usually familiar with community members' gardening experience, and decides which seeds would best suit gardeners' needs based on that. One SL is only open to the general public at events occurring once every 1.5 years.

Beyond the obvious name, shared model, and accessibility, there are other reasons a public library and SL partnership makes sense, such as opportunities for financial support for SLs. In this study 22 SLs located in public libraries had at least some staff time for SL work paid by the library. Although this was not quantified, multiple library employees interviewed for this research reported receiving early support for their SL from the federal Library Services and Technologies Act funds managed at the national level by the Institute of Museum and Library Services, and administered in California by the California State Library.[12]

Public libraries also obtain benefits from SLs they house. Multiple public library employees described SLs as appropriate additions to new alternative lending initiatives that include musical instruments, tools, toys and games. Public librarians in Missoula, MT noted, "public libraries have a new mandate to surprise their patrons and community with innovative services and resources that move beyond the traditional expectations of book management and book provision. Seed libraries are a terrific example of 'outside the box' library service delivery" (Alger et al. 2014). For some of the SL managers who are library employees that I interviewed, their SL has become a new point of contact and work with other organizations and members of the community. For example, one branch librarian noted that the SL has been a part of a Partnership for Healthy Communities project, including collaboration with local farmers, EBT

[10] Refers to town, city or other incorporated area of that name, and found in the US Census.

[11] Calculated from the poverty threshold; guideline for a family of four in January 2015 was $24,250 https://aspe.hhs.gov/computations-2015-annual-update-hhs-poverty-guidelines-48-contiguous-states-and-district-columbia#d.

[12] Library Services and Technologies Act. http://www.ala.org/advocacy/advleg/federallegislation/lsta. Institute of Museum and Library Services. https://www.imls.gov/. California State Library. http://www.library.ca.gov/. All accessed 9 Aug 2017.

Table 4 Founding, hours of operation and work for California seed libraries in this study (n = 45)

	In public library (n = 30)					Not in public library (n = 15)				
	Mean	Standard deviation	Median	Min	Max	Mean	Standard deviation	Median	Min	Max
Year SL founded*	2014	2	2013	2010	2016	2010	6	2011	1996	2016
Hours										
Open/month*	180	55	176	1	264	92	145	28	0.2	500
Unpaid work/year[a]	234	366	136	0	1440	401	545	173	0	2000
Paid work/year[a]	86	139	32	0	600	156	266	45	0	1000
Total work/year[a]*	308	405	205	6	1595	557	544	295	80	2000

*Public library SL location versus other SL location significantly different, $p < 0.05$

[a]Includes seed garden work where applicable

Table 5 Seeds and their original sources for California seed libraries in this study (n = 44)

In the seed library's complete collection	Mean	Standard deviation	Median	Min	Max
Species	43	38	30	5	147
Varieties	128	127	92	1	501
Percent of seed library collection originally from					
Commercial seed	75	30	90	0	100
Gardeners, farmers (grown ≥5 years)	15	21	7	0	90
Other seed libraries	6	19	0	0	95
Other sources, including nursery starts	3	10	0	0	50

(state run Electronic Benefit Transfer) programs at farmers markets, and public health workers.

Being located in a public library can provide SLs with space, more public access and other support, but some SL managers also described challenges with this arrangement. They reported differences in individual public libraries' ability or willingness to support SLs with physical space, access to library webspace, and ease of scheduling complementary activities such as workshops. Some also commented that while it is sometimes possible to obtain start up funding for a SL, ongoing support is difficult to secure.

Most SLs operate because of many hours of unpaid, and sometimes paid work. That work takes many forms, from individuals working alone as needed, to regular group gatherings for activities that include seed cleaning and repackaging, seed garden work, seed and garden education, socializing and sharing food. The hours reported in Table 4 may include time spent buying, soliciting or collecting seeds; repackaging seeds; organizing, and inventorying seed collections; educational activities including talks, classes, exchanges; staffing the SL; and, growing seed gardens to supply the SL.

For all tribal and 73% of public library SL managers interviewed, some SL work is part of their paid duties. Two SLs reported operating with less than 10 hours of total work per year, soliciting commercial seed donations and putting out those packets several times annually. Total hours of work are greater for SLs not housed in public libraries, though not significantly so ($p = 0.0505$). At some SLs, high school students receive community service credit for work, and garden club members, retired people, enthusiastic patrons and others also contribute unpaid work. In a few locations, University of California Cooperative Extension volunteers have also been involved, especially in educational programming for SLs, and two are SL founders.

The hours of work invested in some California SLs is substantial, and evidence of the commitment of the SL workers involved. Calling the unpaid work "volunteer," that is, by "a person who freely offers to take part in an enterprise or undertake a task"[13] implies a more passive role than is true of many SL workers, and especially managers. While it needs better understanding, "pro-bono activists" may be a more appropriate description of these SL workers, as many are establishing and defining the SL and its course of work, and see it as part of larger issues they care about deeply.

[13] Oxford English Dictionary Online. 2017. https://en.oxforddictionaries.com/definition/volunteer. Accessed 9 Aug 2017.

Seeds in California seed libraries and how they move

California SLs offer borrowers a diversity of plant species, and sometimes multiple varieties of those species. The estimates in Table 5 include flowers and edible herbs, and for three SLs some medicinal and ceremonial plants as well.

According to SL managers, many seeds offered by SLs are of species and varieties identified as being easy to grow and save seeds from by sources of information important for California SLs.[14] For example, growing species with seeds that are easy to see and save, and are predominantly self pollinating, such as peas (*Pisium sativum*), and many common beans (*Phaseolus vulgaris*), encourages seed saving and makes it easier to control unwanted gene flow. Other criteria include being popular for eating, and personally or culturally meaningful to gardeners. Tomatoes were a favorite crop of borrowers for 82% (31/38) of SLs; one SL had 12 different varieties, and another had 167 varieties from a large donation! Other categories of common US garden crops popular at SLs are lettuce, sweet and hot peppers, herbs like parsley and basil, and sunflowers and other flowers. Two of the tribal SLs offer seed of regional native edible, medicinal and ceremonial plants known to their communities, and sometimes offer the plant parts themselves for direct use, for example in ceremonial regalia. At least three SLs are now each custodians of varieties of common bean known to have been continuously grown for decades in their respective areas by local gardeners or farmers. Among other seeds particular to certain SLs are diverse Asian greens, edamame, chilis, luffa, and grains including rye, quinoa and wheat. In addition to seeds, three of the SLs in this study also offer vegetative propagules of perennial plants: freesia bulbs, some native edibles and medicinals, and cuttings of grape, raspberry and walnut.

To understand seed stock being offered by SLs, managers were asked to identify what proportion of their original collection came from different sources, based on the first time it entered the SL's collection. A distinction was made between gardener or farmer seed donations and seed returns of material originally borrowed from the SL, grown out and then returned to it. Gardener or farmer seed as defined in this study had been grown for at least 5 years by them, and first entered the SL when they donated it. This definition was based on the assumption that 5 years was adequate time to develop a population distinct from the original source, possibly including some local adaptation. Commercial seed grown by a gardener for 1–4 years was still considered commercial seed. Seeds borrowed by gardeners, grown out and then returned to the SL, were not considered gardener-sourced original donations.

For the majority of California SLs, commercial seeds make up most of their original seed collection. Five special purpose or mission-driven seed companies were the most common source of commercial seeds, as donations or purchases (see ESM Table S3). There was no significant difference in the original sources of seeds between SLs in public libraries and those located elsewhere (data not shown).

Seed libraries differ in how they handle seed returned to them by borrowers. Some SLs never put returned seed out for borrowing out of concern for quality. Most eventually made the majority of returned seed available for borrowers (see Table 5), usually after cleaning or repackaging it. Twenty-two percent (8/36) of SLs performed some type of quality testing on returned seed, including germination tests, or grow outs for evaluation.

Twenty SLs (44%) had a seed regeneration or grow out program for at least some of their seeds, in addition to any seed that is returned by borrowers (see ESM Table S4). Thirty-six percent (16/45) of SLs had a garden, and 20% of the SLs that had grow out programs use their own SL garden as part of that program. The remaining SL gardens ($n=12$) were used for education and demonstration, not seed production. In addition to grow out by gardeners and farmers, other regeneration strategies included a network of families and garden groups at isolation distances growing out the same species, and tribal program gardens.

Ten SLs were conducting intentional selection on one or more of the varieties in their collection, with improving adaption to the local environment a general goal. Nine of these SLs also had more specific objectives, for example: better cherry tomato productivity in the shade; a scarlet runner bean population with improved digestibility by eliminating all but white seed coats; disease resistance, flavor, fruit size, and other post harvest qualities of cucumber, tomato and pepper varieties; multiple, phenologically distinct quinoa varieties; short season tomatoes, and carrots that can overwinter in the ground for high altitude gardens; intentional mixing of fava varieties for cross pollination and selection of new genotypes from the segregating F_1 population (filial 1, the first progeny generation produced by a cross between two distinct parents), with a focus on easy shelling phenotypes; leaf type and post harvest qualities of kale and escarole; adaptation of an alpine strawberry to rooftop growing in San Francisco. Most of these selection projects were being done by 1–3 gardeners, although groups of gardeners are working together to select from a single crop population in two different cases.

[14] The most popular of these, based on California SL manager comments and SL websites include the Community Seed Exchange (http://www.communityseedexchange.org/), Richmond Grows Seed Lending Library (http://www.richmondgrowsseeds.org/), Seed Library of Los Angeles (http://slola.org/), Seed Matters (http://seed-matters.org/), and Seed Savers Exchange (http://www.seedsavers.org/csrp). All accessed 9 Aug 2017.

Table 6 Seed movement in California seed libraries

Seed movement	Mean	Standard deviation	Median	Min	Max
Number of different seed borrowers/year/SL (n = 33)	177	568	43	0.8	300
Number of different seed returners/year/SL (n = 28)	11	27	3	0	120
Overall seed return rate (n = 27)	6%	8%	4%	0%	28%
Annually, seed packet equivalents borrowed/ SL[a] (n = 28)	231	468	51	3	2000
Percent of returned seeds made available for borrowers (n = 27)	78%	33%	98%	0%	100%

[a]Seed library or patron seed packaging was estimated when possible as follows: seed count/packet of 15 popular garden crops (see ESM Table S5), including those mentioned by SL managers, was obtained from Baker Creek Heirloom Seeds website at http://www.rareseeds.com/. Mean count = 134/packet; using this number, commercial seed packet equivalents were calculated based on number seeds SLs reported placing in their own packets

Seed movement, or lack of it, can affect perceptions of SL success. I did not ask what indicators SLs use to gauge success in achieving their goals, but some managers were clear that public engagement, in the form of the number of seed borrowers or the amount of seeds distributed, was their measure of success for achieving goals like greater access to seed, and education. For others, no matter what their goals, seed return has been thought of as the indicator of a successful SL. For example, staff of one public library decided to shut down their SL after 1.5 years because borrowers never returned seed. Inexperience with seed saving, and with sharing of any kind, were seen by SL managers as obstacles to seed return. One manager exclaimed, "Even expert gardeners are not always good seed savers!" Similarly, noting that seed saving can be challenging, Weak (2014) urged fellow public librarians to start SLs with a focus on seed sharing, that is providing access, not seed saving. However, sharing itself may be as novel for some as seed saving, and learning and practicing a "culture of sharing" was cited as a primary goal for 36% of SLs.

Information on seed movement is required and recorded by very few SLs, so the data here are those recorded, or confidently estimated by SLs able to differentiate between seed returns and original donations. For each SL the seed return rate was calculated over the SL's lifetime: (the number of different individuals returning seeds)/(the number of different individuals borrowing seeds). Individuals returning seed, and not seed lots returned, was used because this was much easier to estimate with some confidence. There was great variation in the number of different people borrowing and returning seeds (see Table 6). Among the ten SLs reporting seed adaptation to local environments as one of their goals, the mean return rate of 9.2% was higher, but not significantly so, compared with 4.3% among the 17 SLs not citing seed adaptation as a goal ($p = 0.067$).

However, just as food miles are not necessarily the best indicator of community benefits from food system localization (Cleveland et al. 2015; DeLind 2011), seed return rate seems a poor metric for SL success in terms of many of their goals. Even if seeds are not returned, seeds borrowed from SLs could have important benefits in the community, but there has been no systematic tracking to understand the fate and impact of borrowed seeds socially or biologically. Among the unanswered questions are: Who is using SL seeds? Who is eating the food produced, and how is this affecting them? How are seeds supporting cultural values? How long do those seeds persist in the informal seed systems they move into through seed borrowers and gardeners? Is sufficient change occurring to make varieties more locally adapted and easier to grow?

Selecting indicators of the impact of SLs will need to include not only direct effects, but the experiential learning through seed saving and gardening, which can effect many areas of peoples' lives and communities. Food gardening can help gardeners understand and appreciate natural processes in the environment and their own bodies (Hale et al. 2011). Especially in the poorest neighborhoods, gardens can beautify shared spaces, facilitating positive interactions with natural and social environments (Voicu and Been 2008). It may be that, similar to gardening itself (Litt et al. 2011), the aesthetic or spiritual value of seeds and caring for them can provide benefits that are hard to quantify, but significant for some. For example, one of the SLs in this study is described by its founders as an art project, with the seeds being the starting point for expression, whimsy and community building. Seeds can represent our past experiences, values and plans for the future, but at the same time they are tangible, can be handled, sorted, counted, packaged and stored. This attractive combination of the symbolic and material qualities of seeds has been recognized for a long time in the many traditional, seed-centered ceremonies around the world, and contemporary work such as SeedBroadcast,[15] a "mobile seed story broadcasting station," or SSE's seed stories initiative.[16]

[15] SeedBroadcast. http://seedbroadcast.blogspot.com/. Accessed 9 Aug 2017.

[16] SSE's initiative to collect seed stories. http://www.seedsavers.org/how-to-share-seed-stories. Accessed 9 Aug 2017.

Conclusion

Through SLs community members are creating the seed systems they want, tailoring the biological and social characteristics of these institutions to their values, interests and capacities, and their effort is substantial. Every year about 4776 people borrow seeds from, and 238 people return seeds to, the California SLs in this study; these SLs distribute the equivalent of approximately 6456 commercial packets of seed; and they are able to operate thanks to a total of over 17,000 hours of work annually, with more than 12,200 hours of that being unpaid. These activities, investments, and the goals that SLs state for themselves, indicate they are a meaningful part of the larger food movement.

Using a functional framework makes it possible to discern the different roles assumed by California SLs as institutions supporting alternative, semi-formal seed systems. This is reflected in the different seed system functions that SLs focus on. All are engaged in local, public, non-commercial seed distribution, a key function supporting SLs' defining goal of expanded community seed access. The biological impact of this distribution could range from negligible to significant, depending on the fate of those seeds, which is unknown at this time. Who SL borrowers are and what they do with the seeds undoubtedly varies across different SLs and communities, and understanding this will help SLs better address their goals. Relevant to this, the lack of diversity found in SL management is a reminder to myself and others of our collective, necessary work of recognizing and dismantling implicit biases that are pervasive, including in science (McNutt 2016), and the food movement.

SLs whose goals include local adaptation of crop varieties, or those that wish to be self sufficient for seed, are exploring the seed system functions of conservation, improvement and multiplication. As SLs do this, their impact on the processes that shape crop diversity will expand, as will the challenge of encouraging the benefits and minimizing the shortcomings of those processes in ways consistent with SLs' goals and capacities. This is now a focus of several of the most active SLs. A valid hypothesis to test is that there are biological and social benefits particular to semi-formal seed systems, and those may be best achieved by SLs. For example, combining the benefits of small-scale, local selection and easy accessibility with the capacity to draw upon larger plant population sizes through an active regional network. Diversity shaping processes change some crop populations over very short periods (e.g., 3 years) and at small-scales, as documented in the case of common bean in Europe (Klaedtke et al. 2017). The possibility of creating socially-relevant methods responsive to local selection but maintaining sufficient diversity to continue to adapt could be particularly useful given the regionally variable manifestations of global climate change being observed and anticipated (e.g., for precipitation see Stocker et al. 2013; Rapacciuolo et al. 2014).

As their interaction with the biological material they manage expands beyond the distribution function, SLs could become a form of grassroots, community science focused on the crop genetic resources that are meaningful and useful to them. SLs may then be doing "social movement-based citizen [community] science" (Ottinger 2017), defined and driven by community members and their allies, not professional plant breeders, conservationists or other scientists, and sometimes involving rejection of established methods and metrics. Among SLs engaging in other seed system functions, some characteristics of social movement-based community science are already present (see Ottinger 2016). These include community generated research questions and innovative, locally relevant methods that challenge the relevance of conventional, formal seed system approaches. The potential for experimental community science in semi-formal seed systems to develop institutions, practices, seeds and knowledge for the kinds of food systems valued by a community is intriguing and exciting. This is especially true if such community science can be part of a strategy to achieve the profound, systemic changes needed for positive, comprehensive alternatives to dominant seed, food and agriculture systems.

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