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Promising Strategies to Enhance the Sustainability of Community Seed Banks

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Abstract: Community seed banks are farmer-managed organizations that conserve and sustainably manage local crop and tree diversity. They are found in many countries of the Global South and increasingly in the Global North. Altogether, they maintain hundreds of crop and tree species and thousands of mostly local varieties and distribute tons of quality seed per year. Through their activities, they share and safeguard the world's agrobiodiversity, contribute to seed security, and allow farming households in local communities to produce and consume more affordable, secure, diverse, and nutritious foods. However, community seed banks are knowledge-, resource-, and time-intensive organizations that operate through their members' voluntary contributions. The purpose of this article is to analyze the sustainability challenge of community seed banks and identify strategies that address it. Focus group discussions and key informant interviews were used, complemented by secondary data analysis of research reports and other deliverables, resulting in five case study countries in Africa and Asia. Five promising sustainability strategies can support viable community seed bank development: value addition; nature-positive agriculture; enabling environment and national genebank partnership; networking and digitalization; and modern, low-cost seed quality technologies. Sustainable community seed banks can make important contributions to national seed sector development but they need stronger policy and legal support to maintain their sustainability.



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1. Introduction

A community seed bank, in some countries called community seed wealth center (Bangladesh), farmer seed house (France), (community) seed library (Canada, United Kingdom), and seed reserve (Guatemala), is a farmer-managed organization with the functions of conservation and sustainable management of local crop- and, increasingly, tree diversity [1]. A community seed bank conserves local crop/tree varieties and related knowledge under direct control of the community. Seeds and seedlings are collected from farmers' fields and home gardens and sometimes from the wild [1–3]. Women actively participate and make decisions in many community seed banks concerning the tasks related to seed collection, management and distribution, the organization of meetings and events,

and collaboration with other seed sector stakeholders. Some community seed banks with whom the authors collaborate have only female farmer members, such as Kabudi-Agoro in Kenya and Gumbu in South Africa. Community seed banks are found in many countries of the Global South and increasingly in the Global North, and worldwide, their number is on the rise [4,5].

Community seed banks emerged in the early 1990s, initially as a response to crisis situations. Ethiopia pioneered community seed banks as a response to a devastating famine. With international support, community seed banks were set up and supplied with seeds of preferred crop varieties. In Guatemala and Nicaragua, the first community seed houses and reserves were built after the devastating impact of a hurricane. There were other motivating factors that led to the establishment of one or more community seed banks. In China, community seed banks emerged to maintain both traditional and newly acquired varieties through participatory crop improvement [4]. Very recently, national organizations in Somaliland, South Sudan, and Sudan established new community seed banks for the first time in their countries to deal with seed insecurity, amidst the very fragile situation of conflict and warfare [5]. In Kenya, the first established community seed bank focuses on conserving traditional leafy vegetable seeds to improve nutrition and health through more diverse diets [6].

Community seed banks manage seeds collectively and are usually led by a small committee of 5–7 members who have been elected by the local farming community. The seed storage building can have just one room equipped with shelves and seed containers or it can be larger, with separate rooms for seed conservation, bulk storage of seed, office space, and meeting space. A new type recently piloted in Ghana is a community seed/field bank. This combines seeds stored in a facility and seeds (i.e., plants/planting material) conserved in the fields of farmers, in particular, banana, root, and tuber species. In practice, most community seed banks store seeds only for a relatively short time (one or two seasons) and regenerate seeds regularly through various mechanisms, such as communally managed seed plots (attached to the seed storage facility) or individually managed seed plots. Often, the community seed bank management committee will ask farmer-members with known crop management skills to take responsibility for the multiplication of a certain crop. Each season, available seed is borrowed to interested members (and sometimes also non-members). Dedicated management committee members inspect the quality of all the seed received and distributed and maintain a registry to track all the seed borrowing and returning transactions. Figure 1 presents the regular operations of a community seed bank.

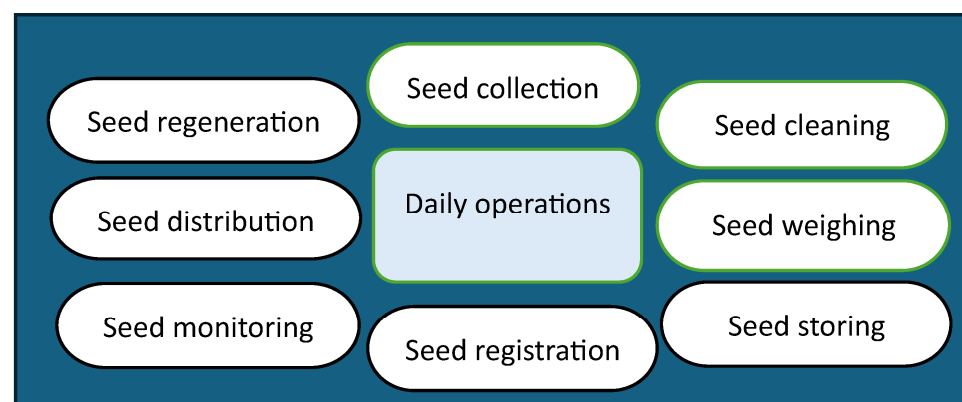


Figure 1. The regular operations of a community seed bank.

Through its operations, a community seed bank can greatly improve seed access to and availability of a large diversity of crops and crop varieties and fruit and timber tree species. Community seed banks also play a role in adaptation to climate change through the deliberate management of crop and varietal diversity [7]. In addition, community seed banks also (i) promote knowledge- and skill-sharing [8]; (ii) build capacity in farm

and natural resource management [9]; (iii) engage with plant breeders to do participatory variety selection for climate-change adaptation; (iv) serve as a platform for community action, social development, and women's empowerment (some community seed banks have one hundred percent women membership); (v) offer credit; (vi) manufacture and sell value-added products; and (vii) represent farmers' views and interests at community and national levels [10]. In some countries, the interactions and joint efforts among community seed bank members are leading to more peace and security [11]. Some community seed banks have become private sector seed producers, delivering large amounts of quality seed to the market and customers (India, Nepal), including a government endorsed certified seed type known as Quality Declared Seed (QDS, Uganda) [12]. Through all these activities, they contribute to several of the (17) goals and associated (169) targets of the "Transforming our world: 2030 Agenda for Sustainable Development" of the United Nations (<https://sdgs.un.org/2030agenda>, accessed on 2 October 2024).

Community seed banks are knowledge-, time-, and resource-intensive organizations that largely operate through voluntary contributions of their members. Community seed banks are usually managed by a small group of farmers elected from the community volunteers, but usually without much managerial and organizational experience. Membership often fluctuates over time. It takes knowledge, skills, time, and effort to run a well-functioning community seed bank and become experienced crop and tree conservationists and seed multipliers and distributors. To deal with the challenges related to this kind of organizational set-up, community seed bank members and their leaders (managers) need to develop the financial, managerial, organizational, and technical skills required to keep the organization viable over time. Community seed bank financial management has received little attention [13]. Economic expertise is particularly needed when the original support to establish a community seed bank ceases because such support is often provided by outsiders (e.g., international or national non-government organizations (NGOs), research organizations, the national genebank). As the accumulated experience of the authors and others has demonstrated, tackling the multiple dimensions of sustainability is a major development challenge [1,14–16]. The purpose of this article is to analyze how community seed banks are addressing this sustainability challenge through innovative strategies and what the emerging results are. The research questions addressed are as follows: (i) What capacities do community seed banks need to contribute to sustainability over time and (ii) how they can acquire these capacities?

Section 2 presents the material and methods of this study, including a brief discussion of the key concepts. Section 3.1 introduces five country case studies (India, Kenya, Nepal, South Africa, Uganda), where community seed banks are piloting new sustainability strategies. The strategies are synthesized in Section 4. Section 5 concludes the article.

2. Materials and Methods

Our work connects to the conceptual domains of organizational sustainability and seed systems and seed sector development, which are discussed briefly in Sections 2.1 and 2.2. Our methods are presented in Section 2.3.

2.1. Organizational Sustainability

Our analysis of the sustainability of community seed banks builds on the extensive literature about sustainable development but zooms in on organizational sustainability. According to Ref. [17], sustainable development requires the integration of three key dimensions: environmental (through the conservation of biodiversity and ecosystems and population control), economic (through production, distribution, and consumption), and social (through progressive culture, proper human resource management, and people's participation). Other authors have argued, building on the work of John Stuart Mill, for a (classical) political economy approach that has a strong integrative power in which history, interdisciplinarity, and social classes are central elements [18,19]. Following Ref. [20], we define organizational sustainability as a comprehensive strategy to build capacity to

respond to environmental, economic, institutional (including political/legal), and social dynamics that shape sustainability outcomes. This definition explicitly addresses the environmental dimension of sustainability, which is in line with Ref. [17].

Environmental sustainability requires optimizing the use of local resources (energy, equipment, labor, land, machinery, seeds/seedlings, storage facility, timber, tools, water) and reuse, recycling, and reduction of waste. Nature-positive and agroecological practices, such as agroforestry, incorporating crop residues in the soil, crop rotation and intercropping, producing and using biopesticides and natural repellents, and water harvesting, contribute to environmental sustainability. The work of Ref. [20] resonates with our previous work on the sustainability challenge of community seed banks, which identified five critical conditions to achieve sustainability: (i) effective operational mechanisms (social–organizational dimension); (ii) legal recognition and protection (institutional/policy dimension); (iii) members having adequate technical knowledge and social skills (social–technical dimension) and resources (environmental dimension); (iv) feasible options for financial viability (economic dimension); and (v) the use of strategic planning from the very beginning.

2.2. Seed Systems and Seed Sector Development

Community seed bank long-term operations include conservation, multiplication, distribution, improvement, and adding value to seeds, mostly of local varieties and varieties improved through participatory crop improvement. When well-executed, these operations can contribute to seed security and seed system resilience, which are core elements of seed sector development. This means that farmers can easily obtain enough quality seeds that they prefer when needed and for a reasonable “price” (most community seed banks distribute seeds on a 1:2 ratio, meaning that for 1 kg of seeds, 2 kg need to be returned after harvest [1]). Community seed banks have their roots in farmer-managed seed systems and community-based seed entrepreneurship, which focuses on household and community livelihoods and fulfilling certain social functions, in contrast to purely commercial seed systems and private sector seed entrepreneurship, represented by national and international seed companies that are formally registered and operate purely for profit. As such, community seed banks have some elements in common with solidarity economy organizations, such as the collective action for the common good, striving for equity, and participatory decision-making [21,22]. In acknowledging the dynamic nature of seed sector development [23], community seed banks can evolve over time from being fully embedded in the farmer-managed seed system to becoming connected to various local markets (solidarity and commercial) and (partially) operating under the formal seed governance regime. They then have similarities with enterprises that Sperling and Almekinders have recently labeled as belonging to the “informal commercial seed systems” [24].

2.3. Methodology

To collect data on the operations, results, and challenges of community seed banks, we used a field-based participatory action learning approach to study and learn from community seed banks in Kenya and Uganda, complemented by a secondary data review of India, Nepal, and South Africa, which together are presented as five country case studies. We used data collected concerning the years 2021 to 2024, which includes the period of the COVID-19 pandemic, during which field activities were badly affected but not completely halted. Field activities included monitoring visits to the community seed banks, targeted training activities, and participatory crop experimentation. Many community seed banks assumed a key role in this difficult period through keeping their doors open and providing access to small quantities of seed, while the formal seed delivery system faced major challenges and, in most countries, could not reach local communities anymore [25]. The methods used include focus group discussions (FGDs) on community seed bank operations and sustainability challenges with community seed bank management committee teams and core members (usually about 10 persons with more or less equal representation of men and women). Three FGDs were held in Kenya and four in Uganda, facilitated by staff of

the Alliance (Kenya) and NARO-PGRC and the Alliance (Uganda) at the premises of the community seed banks. The sessions took place in May and September 2023, and each lasted about 2.5 h.

The topics and key questions of the FGDs were as follows:

- Recognition and support: What types of recognition and support does the community seed bank obtain: financial, organizational, policy/legal, technical? From whom? Under what conditions? What are the challenges? How have these been addressed? What are the results?
- Networking: How does the community seed bank connect to other local or regional initiatives of the same nature? Is the community seed bank linked to farmer organizations or movements? What activities are carried out? What are the challenges? What are the results?
- Collaboration: Does the community seed bank interact and cooperate with the formal (national) genebank and with seed system actors at the (inter)national level, such as plant breeders and seed companies? How does the cooperation work in practice? Do exchanges of seed and related knowledge take place? What are the benefits? What are the challenges? If exchanges do not take place, what opportunities for connection and cooperation are there with each of these seed sector actors?

We also conducted open key informant interviews with professionals from government and non-government organizations about personal and institutional interests and motivation to work with community seed banks, operations of the community seed banks, and the sustainability challenges faced. Professionals included female and male agricultural researchers, extensionists, government officials, national genebank managers and staff, and community promoters. Interviews in Kenya and Uganda were conducted on several occasions during 2023 and 2024 by staff of the Alliance.

The topics addressed were as follows:

- The financial viability and operational sustainability, and options and initiatives to strengthen these;
- Challenges and opportunities of organizational linkages to national or international actors, and new initiatives underway or planned;
- The policy and legal environment, and the related challenges and opportunities.

The field work was complemented by a review of secondary data, including articles, briefs, and technical reports of community seed bank initiatives and projects. The data analyzed concerned the origins and evolution of the number and type of operations of community seed banks, conservation activities and results (number of crops and varieties), seed distributions activities and results (types of channels, seed volumes), engagement in participatory crop improvement and the results, and engagement in value addition activities and the results. Also reviewed were relevant national policies, laws, and regulations that affect farmer-managed seed systems in the five countries, including the recognition of, support to, and collaboration with community seed banks. A review of these policies/laws/regulations in 14 African countries, including Kenya and Uganda, was published as a report in 2023 [26]. All the data were analyzed and organized in the form of country cases studies that include context, community seed bank activities, evolution, results, institutional environment, and challenges.

3. Results

3.1. Country Case Studies

Five country cases are presented, in which each addresses different community seed bank sustainability dimensions, as summarized in Table 1.

Table 1. Community seed bank sustainability dimensions per case country.

Country	Economic	Environmental	Organizational	Policy/Legal/Institutional	Technical
India	X			X	X
Kenya	X	X	X	X	X
Nepal	X		X	X	
South Africa				X	X
Uganda	X		X	X	

3.1.1. India

In India, the seeds of farmers' varieties and landraces are not part of the formal seed system but remain largely farmer-managed. Crop diversity is at the core of smallholder farming [27]. It is a key source of food and nutrition, a buffer against environmental shocks, and a cultural and spiritual treasure [27]. However, across the country, crop diversity is being lost due to agricultural commercialization, industrial food sector expansion, seed production monopolies and the pushing of hybrids, recurring natural disasters, and climate variability. The emergence of community seed banks in India in the 1990s, facilitated by several NGOs, was driven by the need to urgently conserve disappearing traditional crop varieties. Traditional practices of seed saving and exchange evolved to organized community seed banks with support from NGOs and, at a later stage, government agencies alike [28,29]. By and large, community seed banks operate on a local scale and conserve farmer-managed seeds on a short-term basis. These local operations can lead to a larger scale impact when community seed banks network with other seed sector actors. The establishment of the Protection of Plant Varieties and Farmers' Rights Authority (PPVFRA) in 2001, which recognized and incentivized farmers' contributions to conserving plant genetic resources, gave the community seed banks important recognition and support (<https://plantaauthority.gov.in/>, accessed on 2 October 2024). This kind of validation of farmers' knowledge, hardly seen anywhere in the world, energized and motivated many others to start community seed banking to rescue and share traditional climate-resilient landraces.

Since 2010, the Alliance of Bioversity International and CIAT in India (Alliance India team), in collaboration with various public institutions and civil society organizations, has promoted community seed banking as part of a strategy to strengthen farmer-managed seed systems. The novel Seeds4Needs program started community seed banking in 2011 to support the program's participatory variety selection activities aimed at strengthening farmers' adaptive capacities in the light of climate change and improving their livelihoods [30,31]. Between 2011 and 2020, 10 community seed banks were established and equipped with modern equipment and low-cost hermetic storage technologies (combined with the use of zeolite beads, a natural product) to increase seed viability, the longevity of farmers' varieties, and varieties obtained from the national genebank for variety testing. National Genebank and Alliance staff introduced and promoted these modern, low-cost technologies as a means to prolong and increase the storage capability of community seed banks.

More recently (2016–2023), with the support of a United Nation Environment–GEF project (<https://www.thegef.org/projects-operations/projects/5137>, accessed on 2 October 2024), the Alliance India team and partners established 32 new community seed banks at 17 sites, conserving a total of more than 3000 farmers' varieties of more than 25 crops (cereals, legumes, oilseeds, millets, and vegetables). For adopting best conservation practices at the community level, 600 farmers were trained and designated as champion farmers to manage community seed banks. In the same period, ICAR's National Bureau of Plant Genetic Resources, under the National Agriculture Innovation Project "Harmonizing biodiversity conservation and agricultural intensification through integration of plant, animal and fish genetic resources for livelihood security in fragile ecosystems", established 26 community seed banks in three states, i.e., Andhra Pradesh, Himachal Pradesh, and Rajasthan. To create business opportunities for the community seed banks and generate income, interviewed

staff of the support organizations pointed out that all these new community seed banks have a capacity of 15–20 T seed storage, which is much more than in the past. They mentioned that the new operational model is to combine seed storage with large-scale distribution of farmers' varieties of major and minor crops.

According to the evaluation of the functionality and post-project sustainability of community seed banks, it was observed that those community seed banks that operate under a business model by developing value chains of one or more native crops continued to thrive even after project funding ended [32]. In some other cases, such as in Rajasthan, where this did not work, farmers lost interest, and many varieties disappeared from the area. This important lesson about poor post-project functioning led to the development of a new community seed bank sustainability strategy: emphasis on value addition from the very start of a community seed bank and the design of a locally suited business model at once.

To put this new strategy in practice, the Alliance team in India and its partners tested more than 5000 native varieties of 20 crops following a crowdsourcing approach developed by the Seeds4Needs program across four agroecological regions of India [33]. This resulted in nearly 300 native varieties that are potentially suitable for addressing diverse needs, which can be cultivated at scale within a nature-based production environment. For adopting best practices at the community level, farmers were trained and a network of self-help groups (SHGs), farmers' producer organizations, private companies, and local startups was established on value addition and product development for improved adaptation and livelihoods. To generate awareness and to enhance farmers' skills in agrobiodiversity conservation and use, the Alliance India team conducted trainings, awareness workshops, field days, farmers' interaction meetings, and cross-learning exposure visits. To add value, nutrition profiling of selected landraces of target crops was undertaken. Apart from this, other activities, such as branding, trademarking, tag-lining, packaging, labeling, food safety licensing, and the use of media platforms, were organized. As a result, varieties and products marked with different brand names, such as Dhartee Naturals, Gramouday, Hill Hatt, Native Basket, Natural Basket, Sahalee, and Mountain Grains, were developed at different sites by community seed banks (<https://www.thegef.org/projects-operations/projects/5137>, accessed on 2 October 2024). Community seed banks armed with such brand names sell native rice varieties at 30–35 percent higher market rates compared with improved/commercial varieties. Over 30,000 farmer families are benefiting from the variety of activities from production to processing and sale at different sites [34]. Community seed banks were also linked with the hiring and installation of custom threshing/processing machines, such as mini dal mill-cum-graders, oil extractors, mini rice mills, and millet dehullers.

To support the in situ and on-farm conservation management for food and nutrition security and to establish a suitable policy framework, in 2023, the Alliance India team organized a strategic policy dialogue with national and regional stakeholders. The dialogue concluded that the establishment of community seed banks and genebanks can benefit greatly from intergovernmental conventions and mandates of various kinds on issues of sustainable use of agrobiodiversity, access and benefit sharing, indigenous and traditional knowledge, rights of indigenous communities and farmers, and intellectual property rights. Governmental and civil society organizations, as well as international cooperation agencies, can be instrumental in connecting community seed banks with appropriate research and training institutions, such as universities, public research institutes, and private sector or non-governmental research units, to create synergies and contribute to sustainability.

3.1.2. Kenya

In Kenya, an estimated 75–80% of seeds used by smallholder farmers are sourced from farmer-managed seed systems. For generations, farmers have been managing seed and other propagating plant materials through on-farm conservation and deliberate selection for sustainable use. Community seedbanks in Kenya have recently become important actors in farmer-managed systems. In the past four years, there has been a proliferation of

community seed banks, particularly in regions with heightened negative climate change effects. The emergence of community seed banks has been led by NGOs. The Kenya Seed Savers Network (SNN) played a critical role in establishing the first network of community seed banks in Gilgil, which is a semi-arid area with low rainfall, drought, and poor soil conditions. The SNN has since then established more than 50 community seed banks in farmers' homes, where 10–20 families converge to store, save, and exchange seeds. According to interviewed SNN staff, there is a growing demand from farmers to strengthen their farmer-managed seed systems and develop viable farmer-managed seed businesses.

In the past five years, the Alliance of Bioversity International and CIAT, in collaboration with Kenya's National Genebank (the Genetic Resources Research Institute (GeRRI) of the Kenya Agricultural and Livestock Research Organization (KALRO)), established four new community seed banks in three counties, namely, Kisumu, Vihiga, and Kericho, and a fifth will be set up in Kisumu in 2024. The establishment resulted from a subregional project on "open-source seed systems" for climate change adaptation, in which over 1000 Kenyan, Tanzanian, and Ugandan farmers tested over 400 accessions of bean, finger millet, and sorghum from the three national genebanks to identify diversity that is adaptable and well-suited to local climatic conditions. After three rounds of participatory variety selection, the farmers selected the preferred varieties of the three crops, which are currently being conserved in the community seed banks. In addition, a number of seed fairs attracted over 2000 farmers within the project period and led to the exchange of more diversity, which has led to an increase in crop and varietal diversity [35].

The interviewed community seed bank members mentioned that this new diversity encouraged them to explore business opportunities, a challenge that was taken up by the Alliance Kenya team. The team used a value-chain development strategy based on a participatory research and learning methodology to research the current and potential roles of neglected and underutilized species. In 2023, the Alliance Kenya team equipped the community seed banks in Nyando and Vihiga with threshers, seed cleaners, solar dryers, and roller mills. They are now producing quality seed and composite flour made from mixes of the various crops they have grown [36]. They are also producing dried traditional leafy vegetables, which they sell in the markets. Over 200 farmers have been trained in various aspects of quality seed production, and there is a network of over 30 seed producers. At the same time, about 200 farmers have been trained in value addition, including the production of composite flour and snacks from a diversity of 18 crops. The community seed bank management teams expressed their satisfaction about the initial results, which are the beginning of an economic foundation of the community seed banks, but observed that they need to gain more experience to become better entrepreneurs.

Community seed banking in western Kenya adheres to the practice of nature-positive agriculture, which encompasses regeneration, non-depletion, and non-destructive use of the natural resource base and protection, sustainable management, and restoration of the productive systems. Community seed bank farmers explained that they practice agroecological farming on their farms by using locally available resources, intercropping and crop rotation, natural pesticides and organic fertilizers, and non-genetically modified seeds. They also mentioned that they participate in a new nature-positive initiative led by the Alliance Kenya team to practice nature-positive agriculture at the landscape level. Two large-scale farms were established (of 76 and 55 ha) with the support of the county government, where two groups of organized farmers will practice permaculture and other sustainable practices, including the development of equitable and fair value chains for key products. A third group of farmers agreed to coordinate and diversify individual farm production activities across the landscape to create aggregate agroecological benefits.

The interviewed extension staff of SNN described how the organization is addressing this challenge through the establishment of a seed exchange platform (<https://seedexchangekenya.org/>), where farmers are able to exchange seeds of diverse varieties of bean, cow pea, local maize, pigeon pea, sorghum, and traditional leafy vegetables. The website provides the variety description and the agronomic and functional traits and uses, offering basic

information needed to select a variety suitable for agroecological and functional needs. To facilitate the functioning of this platform, the SNN team trained farmers, who have listed their diversity on the platform in quality seed production. Although farmers can exchange seed through this platform, the selling of seed is prohibited under the Seeds and Plant Varieties Act Cap. 326 of Kenya [37]. The interviewed SNN staff remarked that a more enabling environment is critical for community seed bank sustainability. They mentioned that the government is preparing regulations to implement the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and Article 11 (b) of the Kenyan Constitution, which stipulates that the constitution shall “recognize and protect the ownership of indigenous seeds and plant varieties, their genetic and diverse characteristics and their use by the communities of Kenya” [38]. A team of experts is currently reviewing the national access and benefit sharing regulations and the regulations on farmers’ rights. The team is proposing that farmers are allowed to register and sell their varieties. The SNN and Alliance Kenya teams concurred that this is a positive development.

3.1.3. Nepal

Since 1990, community seed banks in Nepal have conserved and sustainably used agrobiodiversity [39]. They also came to the seed re-supply rescue of farmers affected by the devastating earthquake of 2015, when hundreds of families lost their seed stocks [40]. LI-BIRD developed and mainstreamed community seed banking for on-farm management of crop genetic resources and providing effective access to quality seeds and seedlings for food security, nutrition, and climate change adaptation [39]. Over time, LI-BIRD developed a multi-pronged community seed bank sustainability strategy, including five elements: (i) legally registered farmer organizations (e.g., a cooperative) or a local NGO are in charge of management; (ii) community seed banks combine the conservation and promotion of local crop genetic resources with the production and marketing of seeds of registered varieties in large volume and earn some income; (iii) where feasible, a community biodiversity management fund of approximately USD 10,000 is created and mobilized as a soft loan for income generation activities among its members, and the interest generated supports operations of the community seed bank; (iv) a seed fund of approximately USD 5000 is created, which is used for seed business and to maintain a regular cash flow; and (v) a friendly working relationship is developed with the local government and extension agency, so that they allocate land and some financial resources to support the community seed banks [41].

Altogether, the LI-BIRD-supported community seed banks have conserved over 1700 local varieties of 75 crop species. In addition, these community seed banks produced and marketed nearly 400 metric tons of seeds of registered varieties of maize, potato, rice, vegetables, and wheat. These activities have increased crop production, productivity, income, and local employment. LI-BIRD, NARC, and the Alliance of Bioversity International and CIAT supported the registration of 19 crop landraces of seven crop species in the National Seed Board (NSB) by ten community seed banks supported by LI-BIRD [42]. Despite these positive results, community seed banks remain organizationally fragile, operating in isolation and struggling to grow into strong organizations [39].

To address these organizational and networking challenges, in 2023, LI-BIRD and the Alliance of Bioversity International and CIAT supported the establishment of a national network of community seed banks, which was legally registered as the Community Seed Banks Association of Nepal (CSBAN) in 2019 [43]. CSBAN has been facilitating the exchange of seeds and seedlings and related information among the member community seed banks and providing strategic support as per their needs. The interviewed NGO extensionists mentioned that by learning from LI-BIRD, their organizations also started providing support to community seed banks. A recent database jointly updated by LI-BIRD and the Center for Crop Development and Agrobiodiversity Conservation (CCDABC) under the Department of Agriculture (DoA) recorded that there are 47 active community seed banks spread over 40 municipalities/rural municipalities of 29 districts in the country. The

number of community seed banks keeps changing as some become inactive and some new ones are added over time. The new community seed banks are planning to join CSBAN.

In 2019, to strengthen the networking capacity of CSBAN, LI-BIRD, CSBAN, and the Alliance of Bioversity International and CIAT, a mobile seed app called 'Hamro Biu' ('Our Seed' in Nepali) was developed. The app served to list and display the local diversity conserved by CSBAN members. Through the app, requests could be made for seeds and seedlings of associated community seed banks. According to community seed bank management team members, effective and continuous use of the app was hampered by poor internet access and operational challenges [43]. To address these challenges, the app was transformed to a website (www.csbnepal.org), which is expected to function more effectively.

The government of Nepal adopted community seed banking in 2009 and endorsed the "Community Seed Bank Implementation Guideline". The aim was to set up 17 community seed banks led by district-level extension agencies. It was piloted in Dadelhura, Okhaldhunga, and Sindhupalchok districts and replicated in others in subsequent years. Additional policy support came in 2014, when the Agrobiodiversity Policy 2007 was amended to incorporate community seed banking in the community-based biodiversity management program. Since 2022, the Crop Development Directorate of the Department of Agriculture (now the Center for Crop Development and Agrobiodiversity Conservation) has allocated resources to strengthen community seed banks and promote agrobiodiversity on a regular basis. For example, USD 2.08 million was allocated in 2022. There are other national-level planning documents that have incorporated community seed banking to promote local agrobiodiversity, including the National Seed Vision 2013–2025, and the National Adaptation Plan, which envisioned establishing community seed banks by 40% of the 753 local governments by 2030.

3.1.4. South Africa

In South Africa, the government has recognized farm-level crop-diversity management (including by community seed banks) to be effective for agrobiodiversity conservation [44]. Since 2013, the Department of Agriculture, Land Reform, and Rural Development (DALRRD; formerly the Department of Agriculture, Forestry, and Fisheries or DAFF), through its Plant Genetic Resources Centre (housing the National Genebank), in collaboration with the Alliance of Bioversity International and CIAT, has established and financially, organizationally, and technically supported three community seed banks, one in Limpopo (Gumbu, an all-women-managed community seed bank), one in Eastern Cape (Mbobo village, not far from Sterkspruit, Joe Nqabi district municipality), and one in North West province (Jericho). The community seed banks collaborate with other seed sector stakeholders, such as the National Genebank of South Africa (under DALRRD), agricultural departments, plant breeders, and other agricultural/rural development scientists and practitioners. At the end of 2022, the Alliance ceased its collaboration due to termination of the agreement with DALRRD, but DALRRD has continued supporting the three community seed banks. As of 2023, Gumbu had a seed collection of 246 donations of 15 crop and one tree species. Additionally, Jericho conserves 119 donations of 16 crop species, and Sterkspruit, 103 donations of 11 species. All the donations (we cannot use the term varieties, as some of the donations could be identical) are farmer-managed or local varieties [45].

The seed bank farmers in the three locations experienced the impact of climate change through more variable temperatures; changing levels, durations, and intensities of rains; and shifting rainy season starting dates. To address this challenge, the DALRRD team decided to join forces with the Agricultural Research Council (ARC) of South Africa to initiate participatory crop improvement activities. This aimed to support adapting to the changing climatic conditions, strengthening the community seed banks, and building a more resilient seed system. Participatory variety selection was performed on priority crops selected by the farmers (cowpea, okra, pearl millet, and sorghum), with varieties/lines sourced from the National Genebank, ARC, and farmers. These crops are drought-tolerant,

very nutritious, and well-adapted to resource-limited agricultural practices. The best-performing varieties were kept for seed multiplication by the ARC. Seeds were handed to community seed banks for storage and use. Based on FGDs organized at the three sites by DALRRD and ARC, the experiments and direct benefits generated were considered a success. The farmers expressed interest in conducting more participatory variety selection on other important food crops [45].

The model of institutional support set up in South Africa, with DALRRD and the Plant Genetic Resources Centre (PGRC) coordinating and supporting the community seed bank work in the long run, is innovative. It directly connects the ex situ conservation work by the PGRC with the community seed bank activities. It ensures long-term financial, organizational, and technical support to the community seed banks, while the community seed banks can also explore other avenues that contribute to sustainability. In early 2024, DALRRD informed the Alliance that there is interest in establishing more community seed banks across South Africa.

3.1.5. Uganda

In many parts of Uganda, farmers traditionally saved grains and seeds in household granaries. However, due to civil unrest and insecurity, which has caused large-scale displacement of people and dependence on food relief, granaries were abandoned and their use forgotten. Community seed banks, first introduced in 2010 in Sheema, followed by Nakaskeke in 2013 and Kabale in 2015, have gradually become important facilities to conserve seeds. The establishment of community seed banks was started based on the results of research carried out by Uganda's Plant Genetic Resources Centre (NARO-PGRC) together with Bioversity International (now the Alliance of Bioversity International and CIAT) in three districts of western and central Uganda. According to the interviewed NARO-PGRC staff, the findings revealed that farmers were obtaining seeds from several sources, including markets, their own saved seeds, neighbors, friends, and relatives, but these seed sources were not reliable, and the seed was often of poor quality (in fact, the seeds obtained were often grain).

To facilitate timely access to good quality and diverse seeds, NARO-PGRC took the lead in training farmers and establishing community seed banks throughout the country. Community seed banks serve multiple purposes: they connect formal and farmer-managed seed systems; serve as a one-stop center for conserving and sharing non-national catalogue-registered farmer varieties (which are not sold anywhere); revive lost and rare varieties in the farming communities; and research the adaptive capacity of these farmer varieties. Our FGDs revealed that community seed bank membership is increasing, with strong representation of women. Regular monitoring of community seed bank activities by NARO-PGRC indicates that community seed banks increase the crop and varietal diversity in an area over time. They have also given back to farmers the conservation responsibility, ownership of plant genetic resources, and trust in local organization. Community seed banks have been recognized in the National Seed Policy (2018) as key actors in Uganda's conservation strategy (<https://www.agriculture.go.ug/wp-content/uploads/2019/05/Ministry-of-Agriculture-Animal-Industry-and-Fisheries-National-Seed-Policy.pdf>, accessed 2 October 2024). Our FGD data show that to date, three community seed banks have ventured into seed business development, but this has not yet become a common strategy to address economic sustainability. The leaders of these community seed banks interviewed remarked that at the moment, Uganda's seed policy only allows the production and commercialization of formally registered varieties but not of (traditional) farmer varieties.

Currently, NARO-PGRC and the Alliance support seven community seed banks in Uganda; the seventh opened its doors in September 2023 in Masindi. However, through collaboration and partnership with other organizations, several new community seed banks have been set up. Collaborators included OXFAM-Uganda, Participatory Ecological Land Use Management (PELUM-Uganda), and the East and Southern African Farmers' Forum (ESAFF-Uganda). The rapid increase in number led the NARO-PGRC team to

reflect on the policy and institutional dimensions of community seed bank sustainability. As a result, the team developed three instruments for guiding Ugandan community seed bank establishment, operations, and networking. First, the guidelines for establishing and managing Ugandan community seed banks were developed, referred to as its Standard Operating Procedure (SOP). The SOP elucidates the various steps involved and the basic tools and equipment required.

The second instrument is a protocol for collaboration between the National Genebank and the community seed banks, which was developed together with other countries, including Kenya, South Africa, and Zimbabwe, under the guidance of the Alliance of Bioversity International and CIAT and WCDI-WUR [46]. The third instrument is a database website (portal) for all the community seed banks in Uganda (<http://www.csb.naro.go.ug/>). The website is near completion and is updated concurrently with the newest developments. The objectives of the website are to keep track of available materials in the community seed banks, capture and provide feedback, store information, and generate statistical reports of the community seed banks. Currently, of the 25 community seed banks in the country, 11 have already joined the portal, which is housed by NARO-PGRC. According to the NARO-PGRC team, the aim is to further professionalize the platform, connect all the community seed banks in Uganda to it, facilitate the dynamic distribution of seeds and related knowledge, and position the community seed banks at the center of the farmer-managed seed systems in the country.

4. Results: Five Promising Sustainability Strategies

Each of the five country cases addresses several dimensions of the community seed bank sustainability challenge through the piloting of an adaptive strategy. These strategies have produced some first results but still remain a work in progress. In this section, we bring all the strategies together as elements of a new holistic community seed bank sustainability framework that can be put into practice. Table 2 presents the overview; each of the strategies is elaborated in the following paragraphs.

Table 2. Strategies use by community seed banks for five sustainability dimensions.

Sustainability Dimension	Strategy	Case Study Country
Economic	Development of value addition and income-generation activities	India, Kenya
Environmental	Nature-positive agriculture	India, Kenya
Organizational	Fostering national networking and digitalization Enabling policy and legal support	Kenya, Nepal, South Africa, Uganda
Policy/legal/institutional	Developing strategic partnerships with the national genebank	India, Kenya, Nepal, Uganda, South Africa
Technical	Use of modern, low-cost technologies in seed quality management	Kenya, South Africa, Uganda

4.1. Development of Value Addition and Income-Generation Activities

Economic sustainability is one of the major challenges that community seed banks face. This concerns the maintenance of the storage facility, organization of awareness- and capacity-development activities, and engagement with other seed-sector stakeholders. Additionally, it concerns keeping the management team motivated and rewarding them for their time and efforts and creating incentives for members to remain engaged. Experience indicates that where community seed banks receive financial support from one or more other organizations, this challenge may not emerge until this support ceases [1]. Since 2020, as illustrated by the cases of India and Kenya, a new and more coherent strategy has emerged to address this dimension of sustainability value-chain development of local specialty varieties (e.g., black and red rice in India) and of neglected and underutilized species (e.g., finger millet and sorghum in Kenya) conserved by the community seed banks. In Kenya, this led to the production of novel (nutritious) composite flours using/mixing

amaranth, cassava, millets, yellow (instead of white) maize and sorghum for particular consumer groups, e.g., adults, adults with diabetes, and babies. These composite flours offer an alternative to the maize-only based flour, which is a staple food in Kenya used for porridge and “ugali” (mush or pap). This novel healthy and nutritious product development, for which there is growing demand, takes place in the context of maize production suffering from the impact of climate change across East and Southern Africa. In Kenya, farmers started selling the new composite flours in small quantities individually and through the community seed banks of Kabudi-Agoro and Lower Nyando. This promising strategy builds on earlier attempts of community seed banks to generate income from activities directly related to the community seed bank. These include seed sales, which remain a challenge in many countries due to financial, organizational, and policy and legal issues. A key issue remains the difficulty or impossibility of registering farmer-selected or farmer-improved varieties [47,48]. Policy discussions are underway in Kenya and Uganda to address this bottleneck.

4.2. Nature-Positive Agriculture

Researchers in the CGIAR embraced the concept of nature-positive agriculture through the development of a new CGIAR research initiative named “Nature positive solutions for shifting agrifoodsystems to more resilient and sustainable pathways” (known as the Nature+ Initiative; <https://www.cgiar.org/initiative/nature-positive-solutions/>, accessed on 2 October 2024). This initiative is implemented by the Alliance and international and national research partners in five countries, among which are India and Kenya. The initiative builds on the “Boost nature-positive production” pathway, which was one of the five action tracks agreed upon by the United Nations Food Summit in 2021 towards sustainable food systems. The concept of nature-positive agriculture encompasses regeneration, non-depletion, and non-destructive use of the natural resource base, and protection, sustainable management, and restoration of the productive systems. Nature-positive food systems include sustainable and healthy nutrition [49].

Community seed bank farmers in the five case study countries adhere to nature-positive agriculture to varying degrees through the use of various agroecology-based technologies and practices, such as agroforestry, the application of organic manure and natural pesticides and herbicides, composting, drip irrigation, inter- and relay-cropping, mulching, permaculture, and the use of non-GMO seed. The Kenyan community seed bank members in the Kisumu area participate in the Nature+ initiative led by the Alliance Kenya team to practice nature-positive agriculture at the aggregate (landscape) level. Two aggregate farms have been established and are currently being developed through a large variety of productive activities that include bees, crops (food crops and forages), fish, trees, and livestock. In India, community seed banks supported by the Alliance are also taking part in landscape-level agroecosystem management activities, such as land restoration.

4.3. Fostering National Networking and Digitalization

Like many farmer groups around the world, community seed banks operate largely at the local level (village or district) and have limited resources, time, and technological capacity to interact and collaborate with others. This impedes the exchange of experience, knowledge, and seeds among community seed banks from different areas in a country, regionally, and globally. It also hinders the creation of a solid organization that can operate at scale and engage in policy debate and development. The most advanced web platform for community seed banking communication and collaboration is the Uganda case. This serves as a common (national) database to be used for compiling, analyzing, and exchanging data and monitoring operations. The NARO-PGRC team managing the platform developed a simple-to-use community seed bank database checklist (10 key items). The platform connects the community seed banks with each other; it also serves to connect the community seed banks to other seed-sector actors.

The rapid spread of mobile and internet connectivity in many rural areas presents opportunities to digitally network community seed banks. By creating centralized databases and platforms, individual community seed banks can be interlinked to enable coordination regarding access to and sharing and multiplication of seed and related knowledge. Such pooling also allows other seed-sector actors to interact more easily with and possibly support community seed banks. With appropriate information systems, digitally connected community seed banks can integrate into national and global networks to enhance genetic material availability and exchange. However, to date, only limited attention has been paid to this dimension of sustainability. After a pilot period, the SNN seed portal benefited from these improvements, which can also guide other initiatives:

- Increasing seed information and adding an analogue SMS format to cater to farmers without smart phones.
- Developing organizational seed information hubs for e-extension to link with the main portal. The hubs should have the following information: (a) a seed database with names of the farmers, their contact information, and the seed they grow, using a computer program that traces seed records and availability; (b) a seed catalogue; (c) a seed library for seed samples.
- Bulking and saving seeds of rare varieties within each organizational area of work.
- Conducting focus group discussions at the hub level to name and describe all the seed posted online.
- Recruiting more farmers to join and use the platform by conducting four online seed fairs.
- Conducting exchange visits for farmers to interact and learn from each other.
- Holding quarterly consultative meetings for implementing partners.

4.4. Developing Strategic Partnerships with the National Genebank

As already mentioned, the main finding of a recent review of seed (related) policies and laws in 14 African countries in West, East, and Southern Africa is that recognition of and concrete support for farmer-managed seed systems are largely lacking [26]. Much remains to be done to recognize, promote, and support the conservation, distribution, and use of diverse genetic (crop and tree) resources, such as that carried out by community seed banks and local seed businesses. The situation in many countries in Asia and Latin America is not much better and has not changed very much during the last decade. However, in a few countries, more positive developments are underway, from which others can learn and build upon. Among those are the exemplary cases of India, Nepal, and Uganda.

Kenya, South Sudan, Tanzania, and Uganda, inspired by the examples of Nepal and South Africa documented in this article, endorsed a protocol for collaboration between the national genebank and community seed banks. The protocol was developed by several national government units and NGOs in East and Southern Africa with the support of WCDI-WUR and the Alliance of Bioversity International and CIAT. In Kenya, networking and cooperation between community seed banks, the Seed Savers Network of Kenya, and the National Genebank were initiated about three years ago. Farmers visited the National Genebank for the first time and learned about its operations. The National Genebank offered seed of some of its vegetable accessions of crop varieties lost in communities, a move that led to an agreement to explore more collaboration in the future. Community seed banks are acknowledged as important actors to support community-based management of biodiversity in partnership with the Kenyan National Genebank [50].

The protocol promotes a system in which *in situ* and *ex situ* conservation are connected and complement each other instead of being separated and operating in silos. The protocol has articles on (i) the functions and activities of the national genebank; (ii) the functions and activities of community seed banks; (iii) the basic rules and regulations of working together; and (iv) joint initiatives to be organized. The proposed joint initiatives will lead to more sustainable community seed bank operations. Some examples are as follows: (i) broadening the functions to operate as a community development and learning

center (e.g., as is already happening in the case of the community seed banks of Hoima, Joy and Family Farm, and Kiziba in Uganda, and Kabudi-Agoro and Lower Nyando in Kenya); (ii) conducting research on seed storage, conservation, and multiplication methods; (iii) fostering seed business development (e.g., the India, Kenya, and Nepal cases); (iv) introducing participatory crop improvement; (v) producing locally adapted seed for wider distribution, through targeted multiplication; (vi) bringing back varieties that disappeared from the community; and (vii) using modern communication technologies to increase efficiency and effectiveness.

4.5. Promoting Low-Cost Technologies in Seed Quality Management

One of the technical challenges that community seed banks face is to store seeds effectively for one to a few years. It requires that the general scientific principles of quality seed control need to be respected. Most community seed banks use local materials and indigenous practices for storing seeds and seedlings, including clay pots, dried bottle gourds, granaries on stilts, bamboo poles, mud, stones, and straw. Seeds are sun-dried and then cooled before they are packed and stored. Various local practices are used to deal with factors that affect seed quality (humidity, diseases, and pests), such as (i) using cooled-off ash to mix with the seeds; (ii) using dried cow dung on top of the seeds; (iii) smoking seeds above a fire; (iv) and using natural repellents. These methods work very well but can be complimented by modern ones, which can increase efficiency.

The first modern practice is the use of airtight containers, which can range from small-to medium-sized plastic jars to metallic silos. The foremost novel seed storage technology introduced by research partners is the use of various kinds of desiccants, which are easy to use and cost-effective at the same time. WCDI and the Alliance of Bioversity International and CIAT have introduced and trained community seed banks in Africa, Asia, and Latin America in the use of zeolite beads (a clay-type of bead), which are added to seed containers to absorb moisture, then removed after some time and dried in an oven, after which they can be used again [51]. To monitor the seed moisture content, a hygrometer can be used to monitor the temperature and relative humidity in the containers and in the storage facility. Regular field inspections of the seeds conserved by the use of these modern methods by national organizations and staff of WCDI and the Alliance of Bioversity International and CIAT in India, Kenya, South Africa, and Uganda reveal that the seed quality is good, and that longevity has increased compared with seed from before the introduction.

5. Discussion and Conclusions

The five cases presented in this article demonstrate that the effectiveness and sustainability of community seed banks can be enhanced through the adoption of one or more of the tested strategies, leading to enhanced environmental, financial, institutional (policy), social, and technical capacities. We hypothesize that the inclusion of all five strategies together will lead to very solid sustainability.

Based on the analysis of the experiences of the community seed banks in the five case study countries, to develop the promising sustainability strategies discussed in Section 4, we can answer our first research question. The key capacities needed to implement these sustainability strategies effectively are (i) collective and inclusive operational management and continuous learning; (ii) optimum use of traditional and modern seed management equipment, processes, practices, and technologies; (iii) mobilizing support for the development of a supportive institutional, policy, and legal environment; (iv) generating financial incentives for individual members and the collective through value addition and other activities; and (v) efficient use of local resources, including the seed collection, needed for community seed bank operations, based on agroecology and nature+ principles.

When compared to a study of factors enhancing the sustainability of solidarity economic organization in Brazil [52]—several community seed banks in India, Kenya, and Nepal are evolving toward this type of organization—similarities and differences can be observed. Two factors identified are similar: networking and financial support. Two differ:

social incubation and predominant women leadership [49]. The former was not used in the five case study countries. The latter occurs in two community seed banks in the five countries but was not identified as a key factor in our analysis. Through strengthened capacities, community seed banks can become well-organized and well-performing seed-system actors. They can then fulfill seed key sector development roles of (i) digitally supported seed custodians, in particular of local (farmer) varieties; (ii) seed (contract) producers and farmer seed businesses; (iii) producers and sellers of new crop-based products, in particular those that are highly nutritious; (iv) agrobiodiversity conservation collaborators with the national genebank and other seed sector actors; and (v) research partners with plant breeding programs. This resonates well with studies about the key roles required for resilient seed systems and integrated seed sector development [53–55], although our work on digital support for community seed banks has not yet been taken up by others as far as is known. Seed custodianship is also central to studies of the seed commons, agroecological farming, and food sovereignty, which argue for the (re)commoning of seeds throughout the whole seed management process [56].

We will now address our second research question. The five identified key capacities together are the necessary inputs towards the sustainability of the community seed banks and require strong community seed-bank-focused managerial knowledge and skills. The community seed banks in the five case study countries have already acquired some degree of managerial knowledge and skills through learning by doing and through capacity building offered by the supporting organizations. The managerial knowledge and skills could be further strengthened through targeted training offered by professional institutions. Another option could be to establish community seed bank farmer field schools with modules that cover the key activities and capacities. At the moment, there are very few regular community seed bank training courses available anywhere in the world, which is a limitation to further professionalize community seed bank operations.

India, Nepal, South Africa, Uganda, and, to a lesser extent, Kenya are countries that have made a start with providing policy/legal support to community seed banks. The protocol for collaboration between community seed banks and the national genebank was published under the umbrella of the Integrated Seed Sector Africa program (<https://issdafrica.org/>) and endorsed in Kenya and Uganda. Kenya, Nepal, and Uganda have established a digitally supported national community seed bank/seed portal or platform. Community seed banks in India, Kenya, Nepal, and Uganda have entered the local and even national seed market. Community seed banks in India, Kenya, and Uganda have started to produce and sell new products made from conserved crops (e.g., composite flours of grain crops).

Although, indeed, some countries have made a start with creating an enabling policy/legal environment, more (seed) policy and legal support is needed to enable this transition and allow community seed banks to operate as legitimate and viable seed-sector actors. Policy recommendations include the following: (i) create a legal space for the recognition of community seed banks as a type of civil society organization; (ii) include the multiple roles that community seed banks can play in national and sub-national policies and legislation concerning the conservation and sustainable use of agrobiodiversity; (iii) include the funding for community seed banks under the national budget for the conservation and sustainable use of agrobiodiversity and/or plant genetic resources for food and agriculture; and (iv) promote the adoption of the protocol for collaboration between the national genebank and community seed banks.

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