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The roles of community seed banks in climate change adaption

Ronnie Vernooy, Bhuwon Sthapit, Gloria Otieno, Pitambar Shrestha and Arnab Gupta

ABSTRACT

Although community level seed-saving initiatives have been around for about 30 years, until recently they have received little attention in the scientific literature on climate change adaptation and plant genetic resources. Based on research experiences from various countries, this article argues that community seed banks can enhance the resilience of farmers, in particular of communities and households most affected by climate change. Community seed banks can secure improved access to, and availability of, diverse, locally adapted crops and varieties, and enhance related indigenous knowledge and skills in plant management, including seed selection, treatment, storage, multiplication, and distribution.

Bien que les initiatives de conservation des semences au niveau des communautés aient existé depuis environ trente ans, jusqu'à récemment ils ont fait l'objet de peu d'attention de la part de la littérature scientifique sur l'adaptation au changement climatique et les ressources phytogénétiques. Se basant sur les recherches conduites dans plusieurs pays, cet article avance que les banques de semences communautaires peuvent renforcer la résilience des agriculteurs, en particulier ceux vivant dans les communautés et les foyers les plus affectés par le changement climatique. Les banques de semences communautaires peuvent garantir l'amélioration de l'accès à/la disponibilité des cultures et des variétés adaptées au plan local, et renforcer les connaissances et les compétences indigènes en gestion des plantations, y compris la sélection, le traitement, le stockage, la multiplication et la distribution des semences.

Aunque las iniciativas comunitarias para conservar semillas existen desde hace casi 30 años, hasta hace poco tiempo dichas iniciativas habían recibido poca atención en investigaciones científicas sobre la adaptación al cambio climático y a los recursos fitogenéticos. Tomando como base investigaciones realizadas en varios países, el presente artículo sostiene que los bancos comunitarios de semillas pueden acentuar la resiliencia de los campesinos, particularmente la de aquellos hogares y comunidades más afectados por el cambio climático. Los bancos comunitarios de semillas pueden mejorar el acceso a cultivos adaptados a ambientes locales y a variedades diversas, así como su disponibilidad. A la vez, enriquecen los conocimientos indígenas, fortaleciendo sus habilidades en la gestión de plantas, lo cual abarca la selección, el tratamiento, el almacenamiento, la multiplicación y la distribución de semillas.

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Introduction

Climate change is affecting agricultural productivity and food security globally. Global warming resulting in increased temperatures, erratic rainfall, and leading to severe droughts and floods could pose a serious threat to food production (IPCC 2014). One common strategy for adapting to climate change is to exploit genetic sources of resistance to the abiotic and biotic stresses that result from climate changes. Both inter- and intra-crop genetic diversity can be utilised for this strategy. Farmers can use inter-crop diversity by switching to crops that are more resilient, for example, from maize to millets in rain-stressed areas. Or they can use better adapted varieties of the same crop developed through their own on-farm selection, a formal sector crop improvement programme, or a collaborative effort such as participatory plant breeding.

In recent years, scientists around the world have come up with concrete suggestions to strengthen the roles that plant genetic resources can play in coping with climate change. Jarvis et al. (2015) identify several of these concrete actions in the Food and Agricultural Organization of the United Nations (FAO) publication "Coping with climate change — the roles of genetic resources for food and agriculture". They include diversification at species and variety levels; revalorisation of plant species that have been or have become underutilised and neglected; broadening and intensifying the collection, characterisation, and utilisation of crop wild relatives; better targeted plant breeding; and forging better linkages between in situ and ex situ conservation activities. In addition, the authors argue for more policy support to improve access to improved seeds and to allow farmers to produce, save, exchange, and sell seeds. These are all useful suggestions that have been backed up by a number of other authors (for example, Yadav et al. 2011).

Linn (2011) elaborates on the multiple benefits of crop diversification practices such as using varietal diversity in monocultures, mixing crops with non-crop vegetation, crop rotations, polycultures (including wild varieties), agroforestry and mixed landscapes. Benefits derived from these strategies include pest and disease reduction, increased production, increased production stability, and climate stress buffering. Evidence from field trials underway in various countries offers strong support for the use of intraspecific crop diversity within the production system to reduce disease incidence and risks related to climate change (Jarvis et al. 2011a). Such practices will likely also reduce the vulnerability to pest and disease infestations in the future caused by changing climate conditions.

Bellon and van Etten (2014) identify other types of interventions that can support on-farm crop conservation as an effective way to respond to climate change. These interventions include the establishment of a global information system that reports changes in adaptation and evolution processes and enables the localisation of new crop genes and genotypes that can be used in adaptation efforts. They also make the practical suggestion to improve community-based seed saving and storage practices, with particular attention to safeguarding seeds of plants that survive under extreme weather conditions. Sthapit, Padulosi, and Mal (2010) reinforce these suggestions by highlighting the need for more policy support given to the various forms of in situ and on-farm conservation in which farmers and their local forms of organisation should play key roles. The multiple suggestions put forward by all these authors have been brought together in a comprehensive decision-making framework (Jarvis et al. 2011b) that links constraints with action options. The framework also identifies which kind of farmer organisation could be the most effective for implementing each action. A community seed bank is one of the organisational forms included.

Community seed banks are repositories of local genetic diversity that is often adapted to prevailing climate conditions, including biotic stresses. They may be useful to contribute to community-based strategies for adaptation to climate change. However, to date community seed banks have received little attention in the literature related to climate change adaptation. This comes as a surprise given that community-based seed-saving initiatives have been around for about 30 years. Different names are used for these initiatives: community gene bank, farmer seed house, seed hut, seed wealth centre, seed savers group, association, or network, community seed reserve, seed library, and community seed bank (Vernooy, Shrestha, and Sthapit 2015a). The latter seems the most common. This article aims to provide evidence about actual and potential roles of community seed banks in climate change adaptation based on a series of studies that we are carrying out in various smallholder farmer regions of the world. These studies illustrate two important ways in which more effective management of plant genetic resources can strengthen farmers' capacity to adapt to climate change: (1) securing improved access to, and availability of diverse, locally adapted crops and varieties through the use of multiple germplasm sources; and (2) enhancement of related local knowledge and skills in plant management, including seed selection, treatment, storage, multiplication, and distribution. As such, community seed banks can enhance or revive traditional social seed networks that have existed for decades or centuries based on combinations of seed saving, seed exchanges, seed giving, seed bartering, and seed purchase. What is needed now is a growing recognition among policymakers that community seed banks can be a very effective form of farmer organisation toward more climate smart agriculture.

Functions and activities of community seed banks that contribute to climate change adaptation

A community seed bank is defined as a locally governed and managed, mostly informal, institution whose core function is to maintain seeds for local use (Development Fund 2011). Beyond this core conservation function, community seed banks have a broad range of additional purposes and vary significantly in scope, size, governance and management models, infrastructure and technical aspects. There is considerable variability in the performance of community seed banks in terms of technical and operational capacities (e.g. technical rigour in monitoring germination and ensuring viability of stored seed), governance, and operational management. Technical and operational challenges are often compounded by lack of legal recognition and scarce financial resources. Past experience has shown that community seed bank initiatives are usually quite effective during their initial years, but with withdrawal of external support, many cut back on activities or stop altogether. As in other organisational efforts, when community seed banks are established without proper foundations, long-term survival is difficult. Nonetheless, in many countries one can find well-functioning community seed banks (Vernooy, Shrestha, and Sthapit 2015a). In recent years, the number of newly established community seed banks has been on the rise partly due to the growing support of national and state or provincial governments. Examples include in Bhutan, Brazil, Mexico, Nepal, South Africa, India and Timor-Leste.

Based on a global review of the mostly grey literature about community seed banks and a collection of comparative case studies from various parts of the world published in 2015 (Vernooy, Shrestha, and Sthapit 2015a), we developed a framework to identify and organise key functions and activities of community seed banks. The three key functions are: (i) conservation of plant genetic resources; (ii) access and availability of diverse seeds and planting materials according to farmers' needs and interests; and (iii) seed and food sovereignty (Vernooy et al. 2014). Some community seed banks are strictly focused on conservation of agricultural biodiversity including reviving lost local varieties, while others give priority to both conservation, and access and availability of diverse types of seeds and planting materials suitable to various agro-ecological domains. Very few community seed banks explicitly present their efforts as promoting seed and food sovereignty.

Here we expand this framework by identifying activities that are particularly relevant with regard to climate change adaptation. Under conservation these are: conservation of a portfolio of diverse seeds of crops and crop varieties; conservation of seeds from plants that have high capacity to survive under extreme weather conditions; restoration of "lost" varieties, particularly those with good adaption potential. Under access and availability, they are: platform for multiple channels of access and availability of seeds at the community level; accessing novel diversity not conserved locally; accessing seeds from areas where plants have adapted to extreme weather conditions; provision of adapted seed to marginal communities not served by commercial seed dissemination efforts. Under seed and food sovereignty there are no activities that deal explicitly with climate change adaptation. However, the approach known as community-based biodiversity management (de Boef et al. 2013) encourages the search for, use of and control over portfolios of locally adapted germplasm that could be sourced from diverse sources and locations. In the next sections we present a number of community seed banks that put one or more of these climate change adaptation activities in practice.

Review of community seed bank climate change adaptation practices

Conservation: Bhutan, Brazil, South Africa

Analysing the 35 case studies brought together in Vernooy, Shrestha, and Sthapit (2015a), 14 are paying particular attention to actual or expected impacts of climate change. The 14 are from Bangladesh, Bhutan, Bolivia, Brazil, Honduras, India, Mali (two case studies), Mexico, Nepal, South Africa, Uganda, USA, and Zimbabwe. A recently established community seed bank in Bhutan is putting efforts into maintaining existing buckwheat varieties and restoring nearly disappeared ones to enhance genetic diversity in the area in situ, thereby strengthening farmers' capacity to adapt to variable agro-ecological and weather conditions (Tamang and Dukpa 2015). Coordinated by the National Biodiversity Centre of Bhutan, several collection missions were carried to put together a core collection of varieties on the verge of being lost. This collection was then used for seed multiplication and distribution among farmers and storage in the newly established community seed bank. In the state of Minas Gerais, Brazil, community seed banks known as regional seed houses have put great efforts into the identification of the diversity and species density of varieties resistant to climate change. The seed houses plan to multiply and distribute the most resistant varieties at local and supra-local levels (Alvarenga and Dayrell 2015).

Two newly established community seed banks in smallholder farmer areas of South Africa aim to conserve local varieties for the short and longer term and restore varieties that have disappeared from the areas in recent years. They also aim to perform the functions of accessing novel diversity not conserved locally and accessing seeds from areas where plants have adapted to extreme weather conditions. The Gumbu village community seed bank in the dry area of north-eastern Limpopo province is managed and operated by a group of 40 women farmers. The women farmers contend that the community seed bank allows them to maintain a range of different crop species and varieties inherited from their parents. Maintaining crop diversity on-farm not only supports their households in terms of food supply but also gives them satisfaction and allows them to earn incomes from selling seed. However, the production of their food crops is affected by changes in the weather, for example, by changing rainy seasons. In farmers' words, "*rains have not come for a long time*". It has become harder to maintain seeds of traditional varieties, and sometimes their families are forced to consume all their food crops and seeds, resulting in the loss of six of their sorghum varieties, among others. They also expressed that exchange of seeds among farmers of different communities and cultures will help to stop the loss of crop diversity that is occurring in the area and a community seed bank could promote and organise such exchanges, for example, on a yearly basis (Tjikana et al. 2016). Participatory exchanges of seeds among farmers can be an important function of community seed banks to help farmers cope with environmental adversity.

Access and availability: the Kiziba community seed bank, Uganda

Accessing and exchanging climate-resilient seed is one of the most important elements of climate change adaptation, in particular for rural communities. Community seed banks provide avenues for increasing access to diverse seed through various ways. The Kiziba community seed bank in Uganda was established in 2010 in Mbarara Sheema district of western Uganda. Currently, the community seed bank serves about 1,000 farmers in 10 villages. The seed bank evolved from a small group of 30 farmers from two villages with a collection of about 25 local varieties of beans to a collection of about 70 in 2015. In 2014 the community seed bank provided quality seed to 904 farmers in more than 10 villages, totalling about seven tonnes of seeds. Many of the local varieties in the area had been lost over the years due to climate change, increased susceptibility to pests and diseases, and lack of marketing opportunities (Wasswa et al. 2015). With the help of the national gene bank the lost varieties were restored to the community. In total 29 varieties that had been collected in the area were returned.

The community seed bank has five roles: (i) conserving seeds of local bean varieties in situ; (ii) facilitating capacity building of farmers and communities in the production of quality seed; (iii) multiplying seeds of local varieties that are rare and unique or which are becoming less available to farmers, and making them available every season; (iv) assessing diverse materials for different functional traits such as early maturity or drought tolerance; and (v) providing diverse seeds of good quality that have potential to adapt to climate change. The community seed bank has begun collecting seeds from farmers in the neighbouring villages and regenerating planting material that can be stored in the community seed bank to provide diversity. To ensure a sustained supply of seed, farmers who borrow seeds from the community seed bank return double the amount after harvesting. Each farmer is trained in seed production and management to ensure that seed received in the community seed bank is of good quality.

A survey carried out in 2015 of 66 respondents who use the community seed bank reveals that farmers experience noticeable climate change. They mentioned multiple manifestations, such as unpredictable cropping seasons (mentioned by 70% of respondents), unreliable rainfall patterns (84%), reduced rainfall amounts (84%) and temperature spikes (92%). This triggered a discussion among farmers and researchers working in the community about identifying varieties that would perform better under the changing climate conditions. Participatory variety evaluation of the diverse bean seeds available in the area by farmers, breeders, and scientists revealed that of the 70 varieties currently held by the community seed bank, 21 remain popular among farmers especially because they use them for household food security, and also because they rank highly for yield stability, pests and diseases tolerance, and for marketability. The rest of the varieties are grown by farmers for specific reasons not based on genetic traits, such as taste, specific colour, use in cultural festivals, nutrition purposes, such as baby foods, food for breastfeeding mothers, and medicinal purposes. Among the 21 most commonly grown bean varieties, Kiziba farmers prioritised five varieties as the most important for climate change adaptation for being drought resistant, early maturing and resistant to most pests and diseases. The varieties are Nambale, Kakira, Akeru, NABE 14 (a modern variety), and Kankuryemabrukye purple.

Apart from varieties from the community, other varieties have also been identified through the application of a novel methodology to identify and mobilise germplasm based on the use of climate change analysis and geographic information system technologies and software (Vernooy et al. 2016; see below). This resulted in the identification of 10 varieties from the national gene bank that were collected in the country from places with similar climatic conditions as Kiziba, 10 varieties from the Rwanda national gene bank (as part of a community seed bank exchange) and 18 varieties from international gene bank collections (mainly from the International Centre for Tropical Agriculture, CIAT). Of these 18 varieties, 11 are suited for present climate conditions while seven are suited for 2050s climate conditions.

All these newly obtained varieties are currently being multiplied by a national gene bank and Bioversity International research team for further testing and selection by the farmers in this community. The varieties will be conserved by the farmers in the community seed bank and made accessible to the 1,000 farmers who currently use the community seed bank.

The use of a novel methodology

Among the tools used were ArcGIS and DIVA-GIS (www.diva-gis.org) to process multiple site climate data and generate maps of crop diversity richness, distribution of particular crops and their wild relatives and their useful traits, and locations of areas with complementary diversity; MaxEnt (www.cs.princeton.edu/~schapire/maxent) to complement DIVA-GIS to do crop habitat modelling based on species diversity in ecology; and the climate analogue tool introduced through CCAFS (http://analogues.ciat.cgiar.org/climate) to identify analogous climates across space and time – in the past, present, or future. Data analyses were done using R, an open-source software that has multiple functions including generating climate maps, and crop suitability modelling (www.r-project.org). An analysis of climate data for the present and 2050s reveals that temperature and precipitation would increase in the site with a longer rainy season in the 2050s and a temperature increase of about 1.5 degrees Celsius. Farmers in this community would need seeds that are adapted to these "new" climate conditions. Using the above methodology, 11 accessions potentially suitable for present climatic conditions from other parts of Uganda, Ethiopia, and Kenya were identified. Considering the predicted conditions for 2050s, seven potentially suitable accessions from western Kenya, Democratic Republic of Congo, Tanzania, Ethiopia and other parts of Uganda were identified from CIAT collections of East African origin.

Access and availability: community seed banks of the "Seeds for Needs" initiative

"Seeds for Needs" is a major, novel, multi-country initiative developed by Bioversity International that aims to give farmers more access to crop diversity to strengthen their capacity to adapt to climate change and mitigate the risks related to climate change. For example, wheat is particularly sensitive to extreme heat in South Asia when it flowers, so by growing an early as well as a late variety, farmers can increase the likelihood that a short heat period will only affect the varieties flowering at that moment. Furthermore, having a constant stream of different varieties reaching farmers' fields will foster on-farm experimentation and help identify the best varieties for local conditions as a component of a diverse portfolio that can serve as a buffer to climate change. The methodology used is farmer participatory and involves extension workers, agronomists, breeders, and national-level gene bank staff. Together they assess how selected materials perform in different test sites within different agro-climatic zones. Seeds for Needs, first implemented in Ethiopia, India, and Papua New Guinea, has now spread to 11 countries, reaching more than 25,000 farmers in 2015.

Seeds for Needs in India, similar to the work in Uganda, uses modern geographic information system (GIS) technologies and software (DIVA-GIS, MaxEnt, Google Earth) to identify the most promising national-level gene bank resources for testing in rural communities by farmers themselves. To obtain data about farmers' varietal preferences through crowdsourcing trials Seeds for Needs has introduced a number of digital innovations. Farmers' varietal preferences are recorded in the field and uploaded in real time using Open Data Kit servers installed in tablet computers. In India, where mobile phones have expanded widely including into faraway rural areas, this technology operates very well in terms of real-time data acquisition. The initiative makes use of crowdsourcing, an approach used by scientists and companies worldwide to collect data by large numbers of volunteers instead of by just a few researchers. Crowdsourcing the performance evaluation of new crop varieties implies that many farmers carry out small trials, instead of a research station undertaking one large trial. Researchers merge and analyse data from all trials (van Etten 2011). This offers the possibility of testing promising materials in diverse climatic regions, on different soil types, under different management regimes, and, most importantly, under real-life conditions of numerous participating farmers.

Community seed banks did not have a place in the original Seeds for Needs strategy, which focused on making new diversity available and testing it in the field. Little attention was paid to seed production and conservation. This changed when farmers identified promising new varieties and seed demand for these began to rise. For example, a new community seed bank was established in Meket Woreda in Ethiopia in 2014 by the Seeds for Needs research team there to guarantee the provision to farmers of seeds of newly introduced traditional varieties, those most preferred by farmers following several cycles of the crowdsourcing trials. The new community seed banks are being connected to other community seed banks at regular intervals and to the Ethiopian

Biodiversity Institute, the country's leading conservation organisation that manages the country's national gene bank.

In India, farmer research groups involving more than 15,000 farmers are now active in 24 districts in four states (Bihar, Chhattishgarh, Madhya Pradesh, and Uttar Pradesh). After several cycles of on-farm variety evaluation of wheat and rice, farmer groups have initiated seed production and conservation of the best performing varieties. Several of these varieties have traits that allow a better response to climate stresses, such as shorter duration. 2015 data from one newly established community seed bank in Blarampur district of Uttar Pradesh illustrate that of the 92 accessions of 20 crops conserved, 45 or about half have good potential to adapt to climate stresses experienced in the area. Data from the other community seed banks will be collected in the coming period.

Findings from the field trials demonstrated that some varieties that were released for a certain area performed very well in areas where they had not been released. This points to the effects of shifting climatic conditions in the country. Broadening the genetic portfolio of cultivated crops can help in identifying the best-suited set of varieties for a region. Farmers are trained to produce high-quality seeds of these newly identified varieties so that they have enough seeds for the next planting season. Part of the seeds produced goes into the community seed bank together with local/traditional varieties of various other crops. Eleven new community seed banks have been established with the support of the research team and the Indian government through the Indian Council for Agricultural Research (with 20 more in the pipeline) – a clear indication of how the potential of community seed banks can be harnessed.

The core functions of these community seed banks are mainly access and availability, in particular maintenance of locally adapted seed at a low cost, fostering of seed exchanges at local and supra-local levels, accessing novel diversity not conserved locally, and accessing seeds from areas where plants have adapted to extreme weather conditions. The longevity of seeds stored is enhanced using a very innovative technique. The seeds are dried to a very low moisture content (4–5%) using zeolite beads and stored under airtight conditions. According to Ellis and Roberts (1980), low moisture seed storage enhances the seed shelf-life, plus desiccated seeds do not attract storage pests. Even if there is no available reliable power source to run cold storages, the ambient but dry storage has almost the same efficacy. The advantage of these zeolite beads is that they can be re-used many times. A small quantity can be used many times to dry different batches of seeds. All the newly set up community seed banks are equipped with this technology.

Farmers involved in Seeds for Needs envision selling some of the multiplied seed at the local level, an example of the seed and food sovereignty function contributing to income generation. In India, farmers are allowed to sell small quantities of quality declared labelled seed at the local level. The research team together with local partner organisations are training farmers organised in community seed banks in seed selection, treatment, multiplication, storage, and seed marketing to assure that seed quality and diversity are maintained over time. A number of the seed marketing groups are women groups.

Seed and food sovereignty: the community seed bank of Rampur, Dang, Nepal

Established in 2011, the community seed bank in Rampur, Dang, has become a centre for learning about community seed banks in the western terai (lower altitude) region of Nepal. The Dang community seed bank has multiple functions: conservation of rare and unique plant genetic resources; making available diverse types of seeds and planting materials to the local community; enhancement of local fine grain rice variety Tilki; collaboration with extension agencies and private sector for obtaining services and facilitating the marketing of seeds; and promoting seed and food sovereignty in the community.

In Rampur, most of the farmers rely on rainwater for planting rice, the main crop; only a handful of farmers have access to surface water. Due to the lack of water, the majority of farmers used to grow Sarju 52, a rice variety released almost 30 years ago, which is very susceptible to bacterial leaf blight. For many years, farmers were unable to access new varieties of better quality. Thanks to the efforts of the community seed bank, farmers nowadays produce seeds of 26 rice varieties. Among the rice varieties, Sukkha 2, Sukkha 3 and Kachorwa 4 are becoming popular in the area. These varieties have the ability to tolerate drought and require less water compared to other varieties.

Before the establishment of community seed bank in Rampur, Dang, local farmers had to travel to Ghorahi, the district headquarter of Dang district, which is 12 km away from the community, to access seeds. Now, the community seed bank has become the local seed centre of choice for farmers in and around Rampur. Rampur community seed banks offers 33 varieties of cereals, 13 varieties of vegetables, four varieties of legumes, eight varieties of oil seed, six varieties of root and tubers and seven varieties of spices. The Rampur community seed bank produces about 36.5 tons of seed annually accessed by nearly 1,000 farmers.

Creating a supportive policy environment: Central America, Mexico, and Nepal

The efforts of community seed banks to respond to climate change are still in an initial stage. A supportive policy environment could encourage, back up, and solidify these efforts. National seed policies and related laws address seed production, certification, and marketing; variety improvement, registration, and release; protection of intellectual property; and technical support to the seed sector and farmer organisation. A review of such policies and laws suggest that in most countries there is no or little recognition of and support for community seed banks (Vernooy, Sthapit, and Shrestha 2015b). In many countries farmers are not allowed to sell farm-saved seed. In others, legislation to protect farmers' genetic resources is lacking. So far, few countries have explicitly developed or implemented policies regarding the actual and potential roles of community seed banks in climate change adaptation. There is one exception: the countries of Central America. A pioneering example of policy support for community seed banks in the context of climate change adaptation comes from Central America. In Central America, the recently developed "Strategic Action Plan for Strengthening the Role of Mesoamerican Plant Genetic Resources for Food and Agriculture in Adapting Agricultural Systems to Climate Change" (Bioversity 2014) makes community seed banks central. The plan was formulated in 2012–13 with funding from the Benefit-Sharing Fund of the International Treaty on Plant Genetic Resources for Food and Agriculture. Its development involved stakeholders from six countries in the region under the scientific guidance of Bioversity International's Regional Office for the Americas. The resulting plan, supported by the Central American Council of Ministers, is structured in thematic sections focused on in situ/on-farm and ex situ conservation, sustainable use, policies, and institutions. Each section outlines actions to be carried out over the next 10 years. Community seed banks are mentioned across all sections of the plan and associated with a number of priority activities reflecting their multifaceted purposes and legitimacy as local institutions that promote community-based conservation and sustainable use (Galluzzi et al. 2015). Central American governments have started implementing a number of the activities proposed in the plan.

In the ex situ section of the strategic action plan, community seed banks are noted for the role they play in linking formal conservation institutions and farmers, thereby enhancing the flow of plant genetic resources within the overall conservation system, especially those with adaptive traits. Community seed banks are described as decentralised repositories of locally adapted genetic diversity and associated traditional knowledge in the hands of farmers. The plan recognises the contribution of community seed banks to the maintenance of crops and landraces in the territories where they have acquired their distinctive features, and it suggests ways to integrate community seed banks into programmes for strengthening biocultural territories and traditional food systems in the pursuit of food sovereignty, sustainability, and health.

In the section on sustainable use of plant genetic resources, the plan includes the establishment of community seed banks and reserves in climate-vulnerable communities, given their capacity to respond quickly to environmental disasters and contribute to the restoration of local food security. The section on policy recognises the importance of providing institutional support to community seed banks by formally recognising their role in conservation and use of agricultural biodiversity, food security, and climate change adaptation.

A number of other countries have specific policies concerning community seed banks, but omit the climate change dimension. Although in Mexico community seed banks are receiving financial and technical support from the federal government (which makes Mexico one of the pioneers in this aspect) and are now part of the national conservation system, climate change has not yet received much attention (Sánchez, González Santos, and Aragón-Cuevas 2015). With input from NGOs, Nepal's government pioneered a Community Seed Bank Guideline, a comprehensive document developed to guide planning, implementation and regular monitoring of community seed bank activities. The guideline focuses on marginalised, subsistence, indigenous peoples, and conflict-affected households, who often have poor access to seeds. These same households also experience the impact of climate change, although the guideline does not say so explicitly (Chaudhary et al. 2015). At the end of 2014, Nepal also set another precedent when 17 community seed banks jointly handed over safety duplicates of 916 of their own accessions to the national gene bank as a step to strengthen in situ and ex situ conservation linkages and complementarity (Shrestha and Sthapit 2015). After a devastating earthquake hit Nepal in spring 2015, a newly emerging function of community seed bank has received appreciation: a number of community seed banks based in no affected areas were able to provide immediate seed relief. To date, over 20 tons of seed has been provided for rebuilding local seed systems in 10 earthquake-hit districts.

Reflections

The various examples of community seed banks from our global review demonstrate that community seed banks are already carrying out major functions in terms of adaptation to climate change. The Kiziba community seed bank in Uganda is a very good example of the strategy of maximising (bean) diversity to respond to climate change. Farmers have rediscovered the power of crop diversity not only to serve the multiple food security needs of the households and community, but also as a buffer in times of climate uncertainty and stress. The more than 20 new community seed banks being established with support of the Seeds for Needs research teams in Ethiopia and India together with national and local level agencies are a clear indication of how the potential of community seed banks for climate change adaptation can be harnessed. Community seed banks also provide a platform for learning and exchange of knowledge and genetic resources, especially in times of climate change, as the Kiziba example illustrates. In addition, some of them are becoming repositories for indigenous knowledge related to climate change adaptation, among others, through the use of community biodiversity registers (commonly used in Nepal). The community seed bank in Rampur, Dang, Nepal, is an example of building seed sovereignty from the bottom up with a particular focus on climate change adaptation. The community seed bank has become an important local seed centre where farmers can easily access seeds of good quality. It is also serving as a learning centre for other farmers in the western terai region of Nepal.

The central roles assigned to community seed banks in the "Strategic Action Plan for Strengthening the Role of Mesoamerican Plant Genetic Resources for Food and Agriculture in Adapting Agricultural Systems to Climate Change" is unique and highlights the enormous potential that community seed banks have to contribute to effective climate change adaptation. The strategic action plan has yet to be implemented fully, but it charts a broad and practical roadmap for providing policy support at the national and regional levels covering in situ and ex situ conservation and sustainable use under one umbrella. Promising policy development are also taking place in other countries, notably Bhutan, Brazil, Mexico, Nepal, Uganda, and South Africa.

The interaction with, and strong technical support provided by, researchers to guide community seed banks toward more climate change-oriented activities has been central to these efforts. However, this type of farmer-researcher interaction supported by the tools mentioned is still in its infant stage.

The way forward

The examples presented in this article offer some insights in the actual and potential roles of community seed banks. What is needed now are not more studies preoccupied with climate modelling and scenario analysis for the sole purpose of modelling per se, but many more examples of practical efforts of strengthening farmers' capacity to gain better access to crop diversity and use this diversity for current and future needs. These efforts could be supported by policies and laws that aim to:

- encourage the conservation and recovery of local plant species and varieties maintained by smallholder farmers and their communities
- build capacity of community seed banks to strengthen their technical and managerial expertise
- value and reward farmers' individual and collective efforts to safeguard agricultural biodiversity and associated cultural values and knowledge
- value and protect these local genetic resources and related knowledge
- maintain fair access to and availability of these resources (through proper access and benefit-sharing arrangements)
- facilitate links between local and national and international efforts
- support farmers technically and financially to organise themselves, exchange knowledge and experiences, and strengthen their organisational capacity
- disseminate and promote the results realised by community seed banks.

Examples of key policies and laws in this regard include those concerning seed production (multiplication), standardisation, certification, and commercialisation; variety improvement, registration and release procedures; protection of intellectual property (often mostly concerning breeders' rights); technical support to the seed sector (research and extension services); and farmer organisation.

New tools and software can be useful in this regard if and when they are used to respond to concrete interests and needs of farmers and their organisations, including community seed banks. Our review demonstrates that community seed banks can enhance the resilience of farmers, in particular of communities and households most affected by climate change, through securing improved access to and availability of diverse, locally adapted crops and varieties and through the enhancement of related knowledge and skills in plant management including selection, treatment, storage, multiplication, and dissemination of seeds.

The lessons learnt from practice are also valuable to improve concepts and theory of plant genetic resources conservation and sustainable use and the roles of community seed banks in particular. There still remains a lot to be done in this particular field of scientific inquiry.

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