Alliance

Crop diversity, climate change adaptation and resilience: good practice cases from Africa

Photo: Crop and crop variety diversity on display at a seed fair in Zimbabwe.
Credit: The Alliance of Bioversity International and CIAT/R.Vernooy

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Introduction

Across Africa, erratic and less predictable rainfall, higher temperatures, heat spells, and recurring droughts are predicted to become more frequent. This is leading to a change of cropping seasons and growing cycles and occurrence of new pests and diseases. As a result of these irregularities and uncertainties, farmers can no longer rely on crops and crop varieties that used to do well, with negative impacts on nutrition and food security and the capacity of farmers to withstand shocks. One strategy to face this new reality, is to create better access to crop and varietal diversity. Increased access to inter and intra-crop genetic diversity could give farmers an opportunity to switch to crops that are more resilient under new conditions, e.g. a switch from maize to millet in rain-stressed areas. Farmers could also switch to varieties of the same crop that are better adapted to their local situation. However, the potential of local diversity is not always well understood, and with rural populations becoming older and youth migrating to urban areas, knowledge on agrobiodiversity is disappearing.

In recent years, a number of international initiatives have piloted various forms of support for novel configurations of actors to work together to conserve and use agrobiodiversity in sustainable agricultural production systems and to equitably share benefits derived from those activities. The hypothesis informing this research is that crop diversification can result in positive livelihood outcomes, such as food and nutritional security, income generation and good health. These outcomes, in turn, could lead to (increased) resilience of rural households and communities to environmental, socio-economic and climatic shocks. As part of the Integrated Seed Sector Development in Africa (ISSD Africa) program's activities for 2020, the *Agrobiodiversity, seeds and climate change* action learning

group (Theme 3) documented and analyzed a series of good crop diversification practice cases from Africa, which were published in an ISSD Africa working paper [https://hdl.handle.net/10568/115012]. This brief presents a synthesis of the working paper.

The cases present very diverse, but effective pathways of crop diversification and report various positive results and related improved knowledge and skills, e.g. about the multiple functions of biodiversity, management of pests and diseases, soils, water and crops. The cases clearly demonstrate how crucial and valuable agrobiodiversity (including crops, trees and livestock) is for rural livelihoods and economies at large. The studies are based on long-term field research in close collaboration with farmers, their communities and organizations, e.g. farmer field schools (FFS), community seed banks (CSBs), and other stakeholders. Another key feature is that the cases use different system approaches, which go beyond just the production side of farming. Such approaches are instrumental to analyze the dynamics of farming and the linkages that are required to practice sustainable agriculture and contribute to positive livelihood outcomes. The cases show that there is a relatively clearly "visible" causal relationship between crop diversification and diverse positive livelihood outcomes, but they are not conclusive about increased resilience, requiring further research.

Mali: participatory agro-biodiversity management for adaptation to climate change

Over the past three decades, agricultural areas in Mali have been affected by significant climate change, most notably increasing temperatures and a shortening of the rainy season. The effects of climate change and the growing population, which increases the demand for food, make the availability of sufficient food increasingly constrained. A number of projects implemented between 2005 and 2019 aimed to strengthen traditional crop and seed systems in the Ségou and Sikasso regions and the sites of Bolimasso, Boumboro of the Prefecture of Tominian and Somo of the Prefecture of San. The targeted species were millet, sorghum, fonio and cowpea, and, in more recent years, also jute mallow and leaf amaranth. Research and development activities were combined under the leadership of *l'Institut d'Economie Rurale (IER)* of Mali (under the Ministry of Agriculture), in collaboration with many national and international partners.

Three key activities were the implementation of diversity (seed) fields (photo 1), diversity (seed) fairs and (traditional) food fairs, using participatory approaches for the management and conservation of local varieties, with a very strong involvement and participation of farmers and the recognition of their knowledge. This made it possible to establish a local "forum" through which producers obtained improved access to seed of different crop varieties (local and improved) with different traits and growing cycles, ultimately resulting in the reduction of the negative effects of climate change. The activities also created a feeling of trust among producers, strengthening mutual understanding and social cohesion – a form of community empowerment.

Another key activity was the establishment of community seed banks. There are CSBs in Pètaka, Badiari, Gono (circle of Douentza); Fodokan and Socourani (circle of San) and Tassiga (circle of Ansongo). The seven seed banks keep different types of crops and crop varieties. More than seven tons of seeds of different varieties were produced and then marketed and disseminated in different agricultural areas including San and Tominian. The seed banks have effectively contributed to improving the access of producers

Photo 1: Cowpea diversity field, Mali. **Credit:** IER

to seed of different crops and crop varieties that are well appreciated in the diversity fields and at seed diversity fairs. A fourth activity was the selection of improved varieties by local farmers with the support of the researchers. Women's preferences for varieties of different crops played an important role in the selection process. These four activities were complemented and strengthened by value chain development as a means to add value to local crops, diversify income sources, generate employment (in particular for women) and improve nutrition.

Overall, farmers strengthened their capacity to adapt to climate change, and increased their production and monetary income. It also improved the diet of farmers based on the knowledge acquired about the nutritional role of vegetables. The work done facilitated the establishment and consolidation of links between formal and informal local institutions that manage seed conservation and do seed multiplication, while also strengthening the flow of inter-village knowledge exchange and collective modes of action. Last but not least, the agricultural development policy of Mali is now focused on diversification. The key activities put in place by IER and partners align very well with this new policy. The results have contributed to improved seed and food security and adaptation to climate change – all key development goals of the country.

Burundi: local varieties contribute to resilience

In the natural regions of Imbo and Moso, long droughts are causing a gradual decrease in water supply, the drying up of water sources, and a certain tendency towards desertification. In the Imbo region, drought causes a reduction in water resources and a fall in agricultural production. Heavy rains cause severe erosion and flooding in the lower part of the Imbo plain, followed by destruction of socio-economic infrastructure including roads and buildings. In the central plateau region, there is a tendency for the dry seasons to extend from five to six months. The late start of the rainy season and the early end of it are at the origin of the disruption of the cropping seasons and the drying out of crops. The drought has caused the drying up of a considerable number of drinking water points while the too abundant rains cause flooding with significant losses of agricultural production in the marshes.

The aim was to evaluate and offer the best varieties of local crops under the conditions of natural regions with low rainfall (Moso and Imbo). The activities were carried out by *L'Institut des Sciences Agronomiques du Burundi* (The Institute of Agronomic Sciences of Burundi, ISABU) in collaboration with certain Non-Governmental Organizations. Five Communes were chosen for the experiment: three Communes in the Moso natural region, namely, Cendajuru, Gisuru and Kinyinya; and two Communes in the Imbo region, Buganda and Rugombo. The activity was carried out from 2015 to 2019; there was experimentation on taro, yam, cowpea, pigeon pea and sorghum in two regions. The varieties used come from the ISABU (local germplasm) collections kept in the genebank and of each crop, seven varieties were tested; 35 varieties in total. All the varieties tested showed good yields and were offered to the extension services. They were then submitted for registration as customary varieties. The farmers made the choice of varieties to be used according to certain criteria: the vegetative aspect, in particular the tenacity in the face of the absence of rains, earliness, yield, and taste. All the varieties presented an acceptable vegetative aspect and a proven tolerance to drought, which occurs regulalry in these regions.

Farmer associations and pilot producers were trained in seed business development and were registered by the National Seed Control and Certification Office (ONCCS) as producers of traditional crops. This step allowed these traditional crops to be distributed in several regions, marking an important inroad in the seed sector in Burundi. Producing and selling seed has improved income generation of the farmers, ultimately contributing to resilience.

Kenya, Uganda and Tanzania: new varietal diversity for climate change adaptation

In East Africa, climate change has led to increased pests and diseases, low agricultural productivity, food insecurity and general loss of genetic diversity. As a result, farmers have a very narrow gene pool on which they depend. To address these challenges, the Alliance of Bioversity International and CIAT in collaboration with several partners, implemented two projects to introduce and increase the availability and diversity of climate-smart varieties of bean, finger millet and sorghum through testing, participatory breeding and production of high-quality seed in four sites in Kenya, Uganda and Tanzania, in collaboration with local community seed banks.

Over 500 accessions of five key crops were evaluated by over 2000 farmers in the three countries for

Photo 2: Two of the bean varieties conserved in the Hoima community seed bank. **Credit:** The Alliance of Bioversity International and CIAT/R.Vernooy

important traits for climate change adaptation. This "basket" of crop diversity included materials from the national genebanks of Kenya, Uganda and Tanzania. In Uganda, 63 bean and 44 millet varieties were evaluated. In Tanzania, 24 sorghum varieties, and in Kenya, 52 finger millet and 49 sorghum varieties. The evaluation was done through crowdsourcing trials (baby trials) and on-station trials (mother trials) with local checks against the introduced varieties under rainfed conditions. Through on-station and crowdsourcing trials, farmers were able to select the best performing varieties. In Uganda, farmers selected 7 top performing bean and 7 finger millet accessions. In Tanzania, they selected 10 sorghum varieties, and in Kenya, 10 finger millet and 10 sorghum varieties. Some of the selected varieties came from neighboring countries.

The research data were compiled in comprehensive seed catalogues. The selected varieties are now multiplied and further evaluated with the aim to be registered and released as quality declared seed (QDS). As a result, farmers have succeeded in producing considerable volumes of food in addition to strengthening their agronomic skills concerning seed, soil, water, plant and pest and disease management. Various breeding programs now have access to elite lines of sorghum, finger millet and bean that have various traits for climate change adaptation. Some elite lines with good traits have been identified; for example, a Striga resistant sorghum variety in Nyando, and some very high yielding bean and millet varieties.

Another key achievement was the establishment of two community seed banks. The Hoima community seed bank in Uganda is currently conserving 20 millet varieties and 32 bean varieties (photo 2). The Nyando community seed bank in Kenya is conserving 17 bean varieties, 15 millet varieties and 22 sorghum varieties ()ph. A second seed bank, called Upper Nyando, is in the process of being established through (women) farmers' own initiative. Two seed cooperatives have been registered to enable farmers to produce quality declared seed. Currently, farmers in Hoima are multiplying seed on a five acre farm. This seed will be sold under the auspices of their seed cooperative. There are seed custodian farmers who would also like to start producing seed and partner with DashCrop Limited (in Kenya) and other private sector players. Linkages with national breeding programs have been established. The Institute of Biotechnology and Research of Jomo Kenyattah University of Agriculture and Technology is linked to the farmers in Nyando, and has been working with them on participatory variety selection and testing. In Hoima, the Bulindi Zonal Agricultural Research and Development Institute of Uganda's National Agricultural Research Organization, has been working with farmers on the participatory variety selection of bean and finger millet.

Zimbawe: Farmer field schools on participatory plant breeding for improved food and nutrition security

For over 15 years, Community Technology Development Trust (CTDT) has been collaborating with national and international breeding institutions (Zimbabwe's Crop Breeding Institute, CIMMYT and ICRISAT), the National Gene Bank of Zimbabwe, the Department of Agricultural, Technical and Extension Services (Agritex), Zimbabwe's National Crop Breeding Institute, farmers and local government leaders in target districts, and Champion Farmer Seed Cooperative Company, to carry out Participatory Plant Breeding (PPB) in farmers' fields using the Farmer Field School (FFS) approach. The focus has been on Participatory Variety Selection (PVS), Participatory Variety Enhancement (PVE) and

Participatory Variety Development. In recent years, more than 300 FFS plots were established in farmers' fields every year. Women make up over 80% of the active members of the farmer field schools. They are involved in evaluating and selecting the best performing lines and/or new introduced varieties. These women were empowered through training, exchange visits and occupying at least 50% of the positions on the management committees. Through these activities, some of the women graduated into key leadership positions in local government and politics.

The Agricultural Biodiversity program of CTDT is based on the understanding that increasing crop diversity contributes to improved food and nutrition security at household level, also under conditions of climate change. With climate change-induced droughts, there is a very high and increasing likelihood of harvest failure when farmers grow fewer crops and crop varieties. The more crop varieties a farmer plants in any season, the better their chances of harvesting something, as some of the crops will reach physiological maturity even if the amount of rainfall received is below normal/if the rainfall distribution is poor. Over the years, CTDT has made significant efforts to increase the diversity of crops in farmers' hands in sites in over 20 districts, including Mudzi, Tsholotsho, Mutoko, Murehwa, Chipinge, Rushinga and Uzumba Maramba Pfungwe districts. Except for Murehwa and parts of Chipinge, the rest of the districts are located in low rainfall agro-ecological regions of the country.

PVS has resulted in a substantial increase in crop diversity in the local communities, following the introduction of new varieties over a reasonably long period of time. In addition, farmers are now utilizing the new varieties to enhance their food and nutrition security, in particular under the prevailing effects of climate change. Some farmers who have been able to join the group of smallholder seed producers because of the knowledge gained in the FFS (Photo 3). PVE has led to the renewal old varieties; a process which has resulted in the increase in crop yields of old varieties by approximately 10-30% after yield trials were carried out at the end of three seasons of PVE. In addition, it has also been observed that after enhancement, the ability of the old variety to adapt to changing climatic conditions improves to a great extent. Results coming from the field have shown that PVE is very attractive to farmers working in the FFS, as they do not need any materials from outside (the breeding institutes), but work with their local varieties with the aim of improving them. This provides the farmers with a sense of pride. For PVD, the breeders provided the segregating populations. PVD led to an increase of crop diversity in the communities, as farmers select from segregating populations based on their breeding objectives. Farmers who mastered PVD demonstrate greater confidence in farming, most notably women participants. In this process, farmers' selection choices are made based on the changing local climatic conditions. Based on CTDT's long experience, it has been observed that breeders do not always come to the same choices – they may have other criteria for trait selection. The farmer-led PVD has also demystified the idea that ordinary farmers cannot conduct their selections at a higher level than PVS.

The involvement of government partners from research, extension services and the national genebank is key for the sustainability of such projects, as they provide technical backstopping. The involvement of traditional and local governance leadership ensures sustainability, while the involvement of political leadership contributes to policy formulation and implementation in support of smallholder farmers.

Zimbabwe: the importance of community seed banks

Zimbabwe, with an agricultural sector already facing serious challenges, is one of the sub-Saharan countries worst hit by El Niño, a cyclical climatic

Photo 3: Farmers of the Kushinga Farmer Filed School explain their millet breeding experiment.
Credit: The Alliance of Bioversity International and CIAT/R.Vernooy

phenomenon which occurs every 2-7 years. The El Niño effect is characterized by an anomalous rise in the temperature of the central Indian Ocean between December and January. During the years that it has occurred, it has resulted in a significant reduction in rainfall, with serious consequences for agriculture in general, and food and nutrition security in particular, in the entire region. The 1992-93 El Niño-induced drought, was particularly long and intense with a negative impact on crops and livestock, and consequences for millions of people in the sub-region. With the realization that community seed banks could save farmers' agro-biodiversity from being lost in similar cases of drought, Community Technology Development Trust (an NGO) encouraged farmers to build community seed banks in three districts of Uzumba Maramba Pfungwe, Tsholotsho and Chiredzi. Construction of CSBs has continued over the years and to date, CTDT has established 16 community seed banks in 10 of its 22 operational districts.

CSBs provide options for smallholder farming households to conserve, use and exchange seed of local crop varieties. CSBs facilitate the conservation of local seeds through use. Up to 70% of the participants in the CSB projects are women. In terms of empowerment through training, exchange visits and participation in the seed and food fairs, women play key roles and now occupy key positions in the community seed bank management committee. Through these activities, some of the women graduated into key leadership positions in local government and politics. CSBs offer the following services:

- Storage facilities of their seeds from community-based seed production programs.
- Storage facilities for germplasm collected from households (household collections).
- Storage facilities for germplasm collected from other areas outside the farmers' locations.
- Act as seed distribution points during seed fairs, seed selling/ marketing points, and farmer training venues.
- Act as centers of knowledge and information exchange, especially in areas related to seeds within the community.
- On-farm characterization of farmer saved seed.
- Crop improvement by farmers (using PVE).
- Restoration and enhancement of lost diversity.
- Seed exchanges during seed and food fairs.
- On-farm seed multiplication in plots around the facilities.

CSBs have revived the growth of some of those crops that are neglected by government research such as bambara nuts, sorghum, pearl millet and finger millet in communities where these were disappearing. Repatriation of lost varieties from the National Genebank of Zimbabwe has increased the seed in communities through the engagement of farmers in seed multiplication. Exchange visits with farmers to national and international genebanks contributes to farmer empowerment, knowledge acquisition and improves their understanding of issues relating to challenges with crop losses, and the importance of its conservation through use. CTDT took farmers from their operational districts to the National Genebank in Harare and the Southern Africa Development Community Regional Genebank (SPGRC) in Zambia to create awareness.

Kenya: maintaining soil health and agrobiodiversity in Bumula Sub-county, Bungoma

In Kenya, sugar cane production has been in existence since the 1950s. It was introduced as a major crop to unlock western Kenya's agricultural potential and transform it into the fulcrum of economic prosperity in that part of the country. This study explores the cumulative effects of sugarcane farming and other husbandry practices in the context of income sustainability, versus the need for good soil-health and agrobiodiversity in Bumula Sub-county of Bungoma County. The establishment of outgrower companies, namely Mumias (MOCO) and the Nzoia Outgrowers Company (NOCO), led to increased intensification of sugarcane production, with little regard for growing staple food crops by many farmers. Although national rural development programs, such as the Soil and Water Conservation program, the National Agriculture and Livestock Extension program (NALEP), the National Agriculture Accelerated and Inputs Access Project (NAAIAP) and the current Agriculture Sector Development Support Program (ASDSP) have been in place for many years, their focus has been on a very limited number of crops, in particular maize and bean. None of these programs have promoted crop diversification.

The need to have a steady food supply produced by the community itself, triggered the formation of Sustainable Agriculture Development Initiatives (SADI), which is a local community based organization. The organization took a central role in the recruitment and mobilization of farmers, with whom the research team worked

to promote crop diversification and organic farming (photo 5). In the beginning, farmers were trained by the Ministry of Agriculture on various typologies of conservation agriculture, bio-intensive agriculture (compositing, soil tillage techniques, cropping systems, integrated pest and disease management, agroforestry, and simple soil testing techniques mainly concerning organic carbon). Various soil and crop husbandry practices, such as crop rotations and zero tillage, were employed to incorporate the innovation packages aimed at restoring the soil potential. Farmers then implemented these technologies gradually by growing different crop types, such as local vegetables, cereals and pulses, during the study period. At each stage or level of operation, data were collected. Parameters for data collection were mainly germination population and amount of inputs applied, as well as yield per unit area. Both progressive monitoring and summative follow-ups were used throughout the study period. The collected data from the harvests and descriptive feedback from the farmers on the changes in the yield and restoration of the soil productivity vigor, were analyzed and then shared with farmers. Several initiatives were organized to further disseminate the findings.

Production improved in yield due to improved soils. A case is banana, which increased from 6 kilograms to 13 kilograms per bunch. Many farmers gradually embraced the growing of other food crops along sugarcane as a form of diversification, to become more resilient against the vicious hunger-pangs amongst many households. Each household now has nearly 30% of the crop land under different crops and agroforestry trees. Many farmers are now planting horticulture crops and sell them on the market for income generation. The opening up of small village market joints, where women sell food-wares grown on their own farms, has opened up an alternative source of income as opposed to over reliance on sugarcane income that would have previously been earned.

Photo 4: Farmers actively involved in a field day at SADI's demonstration site in Lwanda village, focused on growing African leafy vegetables, orange-fleshed sweat potato and maize agrobiodiversity (July 2020). **Credit:** SADI

From the South to the South: improving and diversifying planted forages through selection, breeding and inclusion in local production systems

Livestock based systems provide livelihoods to 1 billion people and account for 40% of global agricultural gross domestic product. Animal-source foods provide 14% of the calories and 33% of the proteins consumed globally, and provide essential micronutrients, such as vitamin A, B-12, riboflavin, calcium, iron and zinc. In addition, livestock has high cultural and social values. Producing feed for livestock uses about 84% of the world's agricultural land. The share is even higher in developing countries. Producing enough animal feed is a challenge, especially in ruminant systems, accounting for 50 to 60% of the total production costs. Land resources that can be used for feed production are increasingly constrained. In the face of climate change and its expected negative impacts on livestock systems, adaptation and increasing the resilience of livestock production systems should be a priority. Regions identified as the most vulnerable, e.g. sub-Saharan Africa, are also regions where rural communities rely the most on livestock for nutrition security, income and livelihoods. Well-adapted forages with high productivity and nutritional quality can provide animal feed throughout the year while mitigating GHG emissions. They are amongst the most promising innovations in the livestock sector.

The Tropical Forages Program of the Alliance of Bioversity International and CIAT and its partners, contributes to the wide-scale implementation of multiple-win forage interventions. The forages program started working in Africa in the late 1980s, expanding the Latin American Tropical Pastures Evaluation Network (RIEPT, its Spanish acronym) to West Africa under the name of RABAOC (Réseau de Recherche en Alimentation du Bétail en Afrique Occidentale et Centrale). RABAOC was a collaborative research effort between CIRAD-EMVT, ILCA, CIAT and NARS to conduct adaptive research on forage species in humid and sub-humid West and Central Africa. However, more intensive on-the-

ground presence of the Alliance started only about a decade ago, through the development of a systems approach to forage based crop-livestock-tree systems. That prompted closer interaction with forage improvement through selection and with the breeding of forage grasses of the *Urochloa* and – more recently – the *Megathyrsus* genera to target specific lines and their management for Africa. By integrating improved forages in local livestock production systems, the Alliance's tropical forages program explicitly aims to simultaneously enhance livestock production, natural resource use efficiency, biodiversity and climate change resilience, and mitigate GHG emissions.

The key methodological approaches employed are:

- identification of target production areas and markets in West and East Africa through foresight, ex-ante assessments and spatial analyses;
- from genebanks to improved hybrids: a multidisciplinary pathway to deliver genetic gain;
- assessment of local adaptation and promotion through multi-locational trials addressing constraints in forage seed supply systems;
- quantification of environmental impacts and trade-offs/synergies;
- use of social and gender analysis to understand gender-disaggregated barriers and to develop incentives for wide-scale adoption;
- identification of business opportunities around cultivated forages and forage seeds;
- engage in awareness creation and capacity building through media, traditional and digital extension and outreach;
- engagement in policy-making processes to support the adoption of forages and efforts for sustainable intensification.

The intensification of systems can create opportunities for scaling forages in partnership with both the public and private sectors. Specific benefits for women and youth exist in terms of reducing time to source feeds and developing small-scale business opportunities, such as the multiplication of planting material, and production of hay, silage or fresh fodder, and forage sales. In Africa, the Alliance currently focuses on a few selected countries where there is a defined and increasing demand for improved forages, and where intensified systems are solidly linked to growing markets for animal-source foods. These countries are Benin, Ethiopia, Kenya, Madagascar, Mali, Nigeria, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe. Further scaling to other sub-Saharan African countries is expected in the near future.

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Photo 5: Crop diversity on display in Uganda.
Credit: The Alliance of Bioversity International and CIAT/R.Vernooy