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Seeds of Resilience: Novel Strategies for Using Crop Diversity in Climate Change Adaptation

Ronnie Vernooy[a] and Catherine Kiwuka[b]

[a] Bioversity International, Rome, Italy. Email: r.vernooy@cgiar.org
[b] National Agricultural Research Organisation, Entebbe, Uganda. Email: kiwukakathyrn@gmail.com

Introduction

Findings from the field point to a decline in diversity of local varieties in many countries. Future impacts of climate change are expected to become more pronounced in many parts of the world forcing farmers to change their practices and find crops and varieties better adapted to new weather dynamics. Providing farmers with better access to crop and varietal diversity can strengthen their capacity to adapt to climate change. Under supportive policy and socioeconomic conditions, such strengthened capacity could contribute to greater food availability throughout the year, the production of more nutritious and healthy crops, and income generation. Bioversity International and national research partners are implementing a comprehensive seed resilience strategy allowing farmers to access and use plant genetic diversity more effectively in the context of climate change adaptation. The strategy combines the use of climate and crop modelling tools and participatory research methods. Countries where the strategy has been piloted include Benin, Bhutan, Burkina Faso, Costa Rica, Côte d'Ivoire, Guatemala, India, Madagascar, Nepal, Rwanda, South Africa and Uganda.

Climate and crop modelling tools are increasingly used to predict the adaptive capacity of a given crop to expected changes in climate. The results of these modelling exercises can be used to design strategies to access and use crops and crop varieties that are expected to be better adapted to future climate changes in specific locations. The results of these modelling exercises, complemented by additional research (e.g., local crop pest and disease studies, lessons learned from past crop-improvement efforts, technology adoption studies) will help researchers, gene bank managers, extension agents, and farmers gain access to potentially useful plant genetic resources through the multilateral system of the International Treaty on Plant Genetic Resources for Food and Agriculture or other means. Once obtained, these "new" plant genetic resources can be evaluated in target environments through on-farm experimentation over one or more cycles.

Farmers' seed systems under pressure

Estimates suggest that 80% of the seeds on which smallholder farmers in developing countries depend is saved on farm or obtained through informal distribution channels, such as exchanges between farmers, community sharing systems, and local markets. Women farmers play key roles in farmer seed systems, although they are often overlooked by researchers and development personnel, policies, and programs.

This high level of seed autonomy among farmers masks the fact that, almost everywhere, local seed systems are under stress. Agricultural intensification and commoditisation, privatisation of natural resources, and the strong concentration and expansion of corporate power in the life science industries (including the seed industry) are contributing to a decline in collective local management of plant genetic resources for both conservation and sustainable use. Many farming households have become more individualized in terms of decision making and deployment of knowledge, labour, capital and seeds. Traditional seed exchange relationships have become weaker in many areas. Farming practices are becoming more market oriented, and this increased involvement in markets has both benefits and costs depending on local context. Large-scale rural-to-urban migration is contributing to a decline in farming in many countries or transforming small-scale family farming into contract farming. It is also leading to the feminisation of agriculture, increasing the workload and responsibilities of women in many regions. These trends are affecting local seed production, selection, storage, distribution, and exchange practices, for example, through substitution of local varieties with hybrids that can be easily purchased at local markets.

Climate change has begun to put additional pressure on farmers' seed and food production systems and on the multiple functions that they fulfil. Although, in many areas, farmers continue to maintain crop diversity, a significant reduction in the number of crops as well as area planted is occurring. Findings from the field point to a decline in diversity of local varieties in many countries. Future impacts of climate change are expected to become more pronounced in many parts of the world, forcing farmers to change their practices and causing them to search for information about crops and varieties better adapted to new weather dynamics.

A novel research strategy

The strategy that Bioversity and partners has developed has eight methodological steps:

Step 1, **Situational analysis and planning**, explains how to work with farmers and other stakeholders to determine baseline conditions in a community in terms of seed systems and climate change; how to set priorities and objectives; and how to plan research into development intervention.

Step 2, **Data preparation and selection of software**, introduces useful tools, such as DIVA-GIS, Maxent, and Climate Analogues, and explains how to prepare relevant data for a comprehensive climate change analysis.

Step 3, **Climate change analysis and identification of germplasm**, describes the steps in climate change analysis in the context of impact on agriculture and seed systems and how to identify germplasm suitable for the future climate.

Step 4, **Germplasm acquisition**, introduces the International Treaty on Plant Genetic Resources for Food and Agriculture, and explains howto acquire new germplasm while protecting traditional knowledge and taking into account the phytosanitary aspects of seed production and distribution.

Step 5, **Field experimentation**, presents a number of methods for participatory crop evaluation with the newly acquired germplasm in local environments and farmers' fields.

Step 6, **Germplasm conservation**, discusses specific aspects of the conservation of the newly tested germplasm and the various ways in which it can be multiplied.

Step 7, **Participatory evaluation**, presents a global method for evaluating the research process with farmers, gene bank managers, extension agents, and other stakeholders.

Step 8, **Knowledge sharing and communication**, is about sharing research results with the participants as well as with others involved or potentially interested in the results.

Applying the strategy: the case of Uganda (source: Otieno *et al*. 2015)
In Uganda, a team of scientists and extension agents used the strategy to diversify farmers' access to beans, one of the country's key crops for food security. Using climate change scenario analysis, DIVA-GIS and crop suitability modelling the team identified bean accessions with good climate adaptation potential from three sources: (i) the national gene banks in Rwanda and Uganda, (ii) communities in both countries and (iii) international genebanks. In 2014, the first phase of participatory field trials with farmers was realized using materials from the national genebank and locally adapted varieties. In addition, accessions from international genebanks were requested and then tested in the field in 2015. A third source of novel germplasm are farmers' own varieties. Based on an exchange visits between farmers of community seed banks in Uganda Rwanda, a number of varieties of beans were identified and tested in 2016.
More details are given below.

Models suggest that climate change is likely to increase average temperatures in Uganda by 1.5 ºC in the next 20 years and 4.3 ºC by the 2080s. Changes in annual rainfall patterns and total amount of annual rainfall are also expected. Uganda may become wetter on average. The increase in rainfall may be unevenly distributed in space and time influenced by more extreme or more frequent periods of intense rainfall. Besides changes in rainfall, changes in temperature are likely to have significant implications for agriculture, water resources, food security, and natural resource management. Agriculture is likely to be one of the most affected sectors with repercussions on livelihoods of farmers, food security and the environment. The effects of climate change could threaten the survival of crop genetic resources and affect future adaptive capacity. If properly maintained, crop genetic resources will be essential to climate change adaptation in farmers' fields and for breeding programs.

The high diversity within common bean in Uganda and East Africa can be harnessed to adapt local farmers' systems to climate change. Indeed, small-scale farmers can adapt to such change by shifting their crop varieties to those better suited to predicted future environmental conditions. GIS-based selection of varieties is potentially a rapid and cost -effective way to find new and better adapted varieties. GIS tools can be used to search for varieties that have been collected in climatic conditions that are similar to the present and future climate conditions in a particular site. Unfortunately, the problem of the current germplasm exchange system is the potential limit on the amount of germplasm that farmers and plant breeders may access from both farmers' fields and international and national centres that have *ex situ* collections, due to the prevailing national and international policy and regulatory framework.

Two communities, Hoima and Mbarara, in Sheema district in Uganda, were identified by national partners as predominantly bean growing areas that are facing climate-related stresses of increased temperature, shifting seasons and high erratic rainfall. Beans are a key source of protein in the country. The projected climate in 2050 indicates that temperature and rainfall would increase on average by 1 to 1.5°C and 200 mm per annum respectively. This means that new bean varieties would be needed to allow communities to adapt successfully. Based on simulations for these two communities, potentially adaptable bean varieties were identified in regional collections of beans held by CIAT and held by local communities in Uganda and Rwanda.

Hoima at present has higher temperatures of between 23-27°C and precipitation of 700-1000 mm per annum. Nine potentially suitable accessions were identified from Ethiopia and Tanzania in the regional collections held by CIAT. 2050s climatic conditions indicate increased temperatures and precipitation and using GIS-based modelling, 29 accessions were identified from other parts of Uganda, Tanzania, Kenya, the Democratic Republic of Congo and Ethiopia. Climatic conditions in Mbarara –Sheema district at present indicate average temperature and precipitation of between 20 and 23°C and 1000 and 1300 mm per annum. By 2050 temperatures would increase by 1-1.5°C and precipitation by 180 mm per annum. 11 accessions from other parts of Uganda, Ethiopia and Kenya were identified as potentially suitable for present climatic conditions in Mbarara. Seven accessions from western Kenya, Democratic Republic of Congo, Ethiopia and other parts of Uganda were identified as potentially suitable for future climatic conditions. The identified accessions were requested from CIAT, multiplied and distributed to farmers for participatory trials.

In addition, through an exchange visit between two community seedbanks in Uganda and Rwanda, local farmers in both countries were able to identify potentially suitable local varieties. Through participatory varietal ranking of the local varieties they are currently growing and conserving these varieties in the community seedbanks based on traits such as yield, drought tolerance, heat tolerance, water logging, taste and cookability. The Kiziba community seedbank in Sheema Mbarara district in Uganda holding a repository of the community's 47 varieties of beans provided about 10 potentially suitable varieties identified by farmers. These were requested by farmers in Hoima and in Rwanda. Farmers in Bugesera and Gicumbi districts in Rwanda identified 10 varieties of beans that are potentially resistant to climate-related stresses. An exchange of these varieties was organized between the two communities by national institutions.

Resource manual

A team of multidisciplinary Bioversity International researchers developed a resource manual (called a box) with useful references and resources for each of the eight steps of the research strategy. The interactive on-line version can be found at: http://www.seedsresourcebox.org. The book version can be found at: http://www.bioversityinternational.org/e-library/publications/detail/resource-box-for-resilient-seed-systems-handbook/

The resource box is intended for:1) Plant breeders, researchers, gene bank managers, and policymakers with an interest in plant genetic resources; 2) University lecturers and advanced students with an interest in agricultural development, adaptation to climate change, and seed systems; 3) Others involved in the strengthening of farmers' seed systems and their capacity to adapt to climate change. The resource box can be used as: a one-stop shop for finding selected, easily accessible resources to support research on climate change adaptation by strengthening seed systems; a learning aid to build capacity in facilitating, conducting, and participating in such a research process; pedagogical material for higher education classes or on-the-job training workshops.

References

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