Food and Agriculture Organization of the United Nations

EUROPEAN UNION

STRENGTHENING SECTOR POLICIES FOR BETTER FOOD SECURITY AND NUTRITION RESULTS

Crops and varieties

POLICY GUIDANCE NOTE | 15

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STRENGTHENING SECTOR POLICIES FOR BETTER FOOD SECURITY AND NUTRITION RESULTS

This policy guidance note is part of a series that the Food and Agriculture Organization of the United Nations (FAO), the Directorate-General for International Partnerships (INTPA) of the European Commission and other partners are producing to support policy makers in addressing food security and nutrition in their country. Each note provides guidance on sharpening the focus of sector policies in order to achieve sustainable food security and nutrition outcomes.

Contents

Introduction

FAO is among the vanguard of organizations steering the international community towards a world free from hunger and malnutrition within the next ten years, as advanced in the Sustainable Development Goals (United Nations General Assembly, 2015; FAO, 2017a). Food security, according to the Rome Declaration on World Food Security of the World Food Summit of 1996, "exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). The four principal dimensions of food security are the physical availability of food, economic and physical access to food, food use and the stability of the three preceding dimensions over time (FAO, 2008). Malnutrition, on the other hand, "results from deficiencies, excesses or imbalances in the consumption of macro- and/or micronutrients" (FAO, 2008). However, over 821 million people are chronically hungry (FAO, IFAD, UNICEF, WFP and WHO, 2018) while globally over 2.5 billion suffer from malnutrition according to the World Health Organization (WHO).[1] It is estimated that a 50 percent increase in food production is required to nourish the growing human population, which is expected to exceed 9.2 billion by 2050 (FAO, 2017a).

With over 80 percent of the human diet sourced from plants, most of the necessary increase in food production must come from crops, particularly cereals, vegetables, fruits, roots and tubers, which are grown to be harvested for human consumption, livestock feed, energy, or generation of revenue. In this regard, FAO posits that farmers need to grow "a genetically diverse portfolio of improved crop varieties, suited to a range of agro-ecosystems and farming practices, and resilient to climate change" (FAO, 2011a). Because production systems, agro-ecologies and end user needs and preferences vary among farmers, each would, ideally, prefer to cultivate the variety of a crop with traits that most align with their preferences. A plant or crop variety within a species has specific traits that remain unchanged over generations.

To ensure that the genetic potential of particular crop varieties, introduced through natural selection and plant breeding, is translated into tolerance of biotic and abiotic stresses, improved productivity and more nutritious yield from farmers' fields, farmers must use quality seeds and planting materials. Quality, in the context of planting material, refers to the status of trueness to type (often referred to as varietal purity); satisfactory germination and vigour; freedom from other materials, including plant debris, dead or broken seeds, seeds of other crops, weed seeds, noxious and parasitic weed seeds also non-plant materials, and absence of seed-borne pests and diseases. The accruing improvements, termed genetic gains, are complemented by good agronomic practices and optimal management of pests and diseases. However, ensuring that farmers have ready access to sufficient quantities of affordable quality seeds and planting materials of well-adapted crop varieties, a state known as seed security, is not a stand-alone endeavour, but results from a seamless continuum of mutually enriching interventions that commence with the conservation of plant genetic resources for food and agriculture (PGRFA), through their use in demand-driven plant breeding, to responsive seed delivery systems (Fig. 1). This three-module continuum is known as the management or conservation and sustainable use of PGRFA (Mba *et al.*, 2012). PGRFA is the overarching term for the multiplicity of wild and uncultivated ancestors and related species of modern crops, crop wild relatives (CWR), wild plants harvested for food, unimproved and non-adapted materials, farmers' varieties/landraces and modern varieties developed by plant breeders.

The management of PGRFA is recognized as being critical for the attainment of food security and nutrition. Through the Rome Declaration

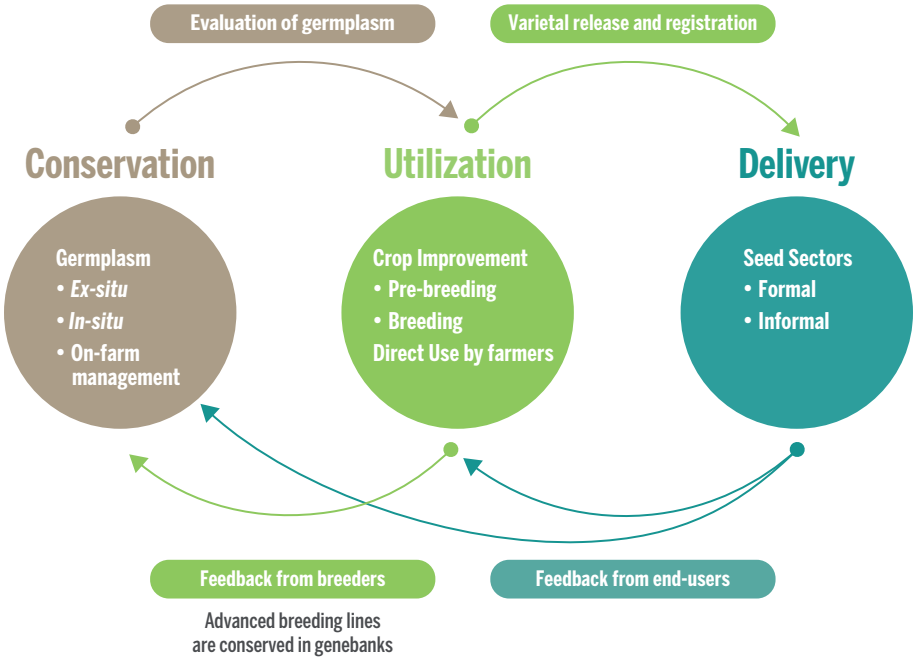
[1] https://www.who.int/news-room/fact-sheets/detail/malnutrition

on World Food Security and the associated World Food Summit Plan of Action, countries committed to "promote access, by farmers and farming communities, to genetic resources for food and agriculture" (FAO, 1996). Through this plan of action countries also explicitly committed to "promote an integrated approach to conservation and sustainable use of PGRFA, through, *inter alia,* appropriate *in situ* and *ex situ* approaches, systematic surveying and inventorying, approaches to plant breeding that broaden the genetic base of crops, and fair and equitable sharing of benefits arising from the use of such resources" (FAO, 1996). The Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (FAO, 2011b), an internationally agreed framework for the conservation and sustainable use of PGRFA, sets out 18 Priority Activities that countries may implement to conserve and use PGRFA sustainably.

The result of these activities is seed security, which contributes directly to the ultimate aim of food security and nutrition. Importantly, in leveraging PGRFA to achieve impactful food security and nutrition, especially in increasingly stressed crop production systems, an underlying principle is that the wider the intra- and interspecific diversity of crops and their varieties, the more resilient and nutritious the cropping system and its products.

Genebank curators, plant breeders, staff of protected areas, other scientists, seed specialists, producers and marketers work collaboratively towards the ultimate goal of translating the genetic potential of PGRFA into improved productivity on farmers' fields with crops and varieties that are more nutritious, more input use efficient and more tolerant to biotic and abiotic stresses. Improvements in seed quality come about through demand-driven and needs-based plant breeding programmes that ideally use the most efficient scientific and technological methods, in collaboration with farmers and other end-users, to develop adapted crop varieties. However, crop improvement programmes cannot function satisfactorily in situations where plant breeders and other scientists do not have access to well-characterized

FIGURE 1: **Strengthening the PGRFA management continuum**



Source: Furman *et al.*, 2021. Conserved and characterized germplasm, which data are accessible, serve as the raw materials for crop improvement, which in turn generate the improved crop varieties which are delivered to farmers through effective seed systems. The feedback loop whereby end-users' preferences shape both plant breeding objectives and germplasm evaluation and promising advanced breeding lines are introduced into genebanks are also equally important. A continuum approach ensures that these three modules are dovetailed seamlessly.

germplasm, which represents the sources of the desired heritable traits they strive to incorporate into elite varieties. Completing the virtuous cycle, the demonstration that improved crop varieties address real life problems, such as enhanced productivity, improved nutritional quality and tolerance to biotic and abiotic stresses – which improve food security, nutrition and livelihoods – serves as the most compelling incentive for policymakers to invest resources in conserving the raw materials used in breeding, both in genebanks and in

nature. Feedback from farmers and other end users, especially on preferred traits, also influences plant breeding goals and decisions on selection for agronomic traits for which germplasm collections are evaluated.

Key messages relating to strengthening food and nutrition security are outlined below.

Purpose of this guidance note

This guidance note is aimed at policymakers and other practitioners who harness PGRFA to achieve improved food security and nutrition. It leverages the Policymaker's Guide, Save and Grow (FAO, 2011a), to underscore the critical importance of crops and varieties to sustainable crop production

Key messages

In order that farmers have ready access to, and can use, affordable quality seeds and planting materials of well-adapted crop varieties, FAO recommends that the following technical, policy and institutional actions be taken at scale, ideally in coordination across sectors and disciplines (FAO, 2011a):

- Strengthen the conservation of PGRFA *in situ* and *ex situ*, their use in plant breeding, and linkages, particularly through improved characterization and evaluation of desired traits in as wide a range of crop species and their wild relatives as possible; increased support for pre-breeding and population improvement and much closer collaboration among institutions that work on the themes.
- Increase the participation of farmers in conservation of PGRFA – both in natural habitats and through on-farm diversity, crop improvement and seed delivery in order to ensure that new varieties are appropriate for target production systems and agro-ecologies and that quality seeds and planting materials of well-adapted farmer-preferred varieties are readily available.
- Improve policies and legislation for variety development and release, and seed supply, including national implementation of the provisions of the International Treaty on Plant Genetic Resources for Food and Agriculture (www.fao.org/plant-treaty/en), enactment of flexible variety release legislation, and the development or revision of seed policies and associated legislation.
- Strengthen capacity, especially by continuously educating new generations of skilled practitioners, to support enhanced breeding and work collaboratively with farmers.
- Revitalize the public sector and expand its role in developing new crop varieties by creating an enabling environment for seed sector development and ensuring that farmers have the knowledge needed to deploy new materials.
- Support the emergence of local, private sector seed enterprises through an integrated approach involving producer organizations, linkages to markets and value addition, and enable public-private partnerships for crop variety development and seed delivery.
- Foster linkages with other essential components of sustainable crop production intensification, including appropriate agronomic practices, soil and water management, integrated pest management, and with other downstream aspects of the crop value chain, such as post-harvest handling – processing, packaging, storage and transportation – and access to credit and markets.

intensification, a means for combatting hunger and malnutrition sustainably. In presenting practical steps that governments may take, for example in articulating policies, it draws heavily from the Second GPA for PGRFA (FAO, 2011b), an internationally agreed framework for the conservation and sustainable use of PGRFA. A recurring theme is that the generation of quality seeds and planting materials of farmers' preferred well-adapted crop varieties, the tangible output for farmers, is possible only because there is an effective demand-driven plant breeding programme which, in turn, functions because of access to the heritable variation that exists in well-characterized PGRFA in genebanks and in nature. While quality seeds and planting materials are considered the means for ensuring that harvests from farmers' fields express the traits bred into crop varieties: they do not just happen, they have to be developed. This policy guidance note articulates the steps that are taken to develop quality seeds and planting materials that need to be made available to the farmers who ultimately produce the world's food.

Background

Crops and varieties – the foundation of agriculture and food production

Agriculture evolved over millennia and through domestication of numerous plant and animal species has produced the rich diversity of crops and breeds that represent the foundation of modern food production systems. The relatively recent emergence of the science of plant breeding, based on the application of genetics to crop improvement, has consciously directed selection for desirable traits that enhance production and nutritional value of numerous plant varieties, many of which directly feed large proportions of the population. This has meant that many farmers and consumers currently have access to a vast array of crop varieties suited to a diversity of environments and circumstances.

PGRFA include the diversity of crop species and the genetic variation that occurs within a single species, the inter- and intraspecific variation. The premise of this guidance note is that PGRFA make important contributions to food and nutrition security if the diversity represented is conserved and used to increase agricultural productivity directly or if it is used to enhance the development of improved crop varieties that underpin food production systems.

The Green Revolution is among the best known examples of harnessing the genetic potential of crops as a component of a complete package that included changes to crop management. The adoption by India and Pakistan of dwarf, disease resistant and input use efficient wheat varieties developed at the International Maize and Wheat Improvement Center (CIMMYT) about five decades ago saved millions of vulnerable people from hunger and starvation. The adoption by various Asian countries of improved rice varieties developed at the International Rice Research Institute (IRRI) resulted in similar impacts on food security and nutrition.

The successes of the Green Revolution relied on access to germplasm collections that were screened for desirable traits – the dwarfism trait in wheat, for example, was sourced from a Japanese accession that was held in a germplasm collection in the United States of America. Genetic materials identified as being potentially useful were incorporated into breeding programmes; several crosses among wheat accessions were made and promising progeny were selected in Mexico. Quality seeds were produced and provided to farmers and transported from Mexico to India and Pakistan with assistance from national governments and various agencies.

The substantial successes of the Green Revolution paved the way for establishing the network of international agricultural research centres that became known as the Consultative Group for International Agricultural Research (CGIAR). The CGIAR has generated public goods and improved crop varieties and accompanying production packages that have contributed immensely to improvements in food security and nutrition over recent decades. The CGIAR centres cooperated with the national agricultural research and extension systems (NARES) of many developing countries, particularly those in the tropics, to develop many of the improved crop varieties that are currently cultivated in those countries. The CGIAR crop improvement programmes have always been underpinned by the large and comprehensive germplasm collections that are global public goods, available to all scientists and organizations that request them.

The governments of previously food insecure countries, for example Brazil, China and India, provided sustained investments to strengthen successfully the institutional and human capacities of their NARES. They established national networks of research institutes to address particular crops and agro-ecologies. The Brazilian Agricultural Research Corporation (Embrapa), in addition to its headquarters in Brasilia, incorporates 43 other decentralized

centres and units.[2] The Chinese Academy of Agricultural Sciences (CAAS)[3] oversees 42 research institutes and a graduate school and the Chinese Academy of Tropical Agricultural Sciences (CATAS) has three campuses, 14 institutes and one experimental farm and also engages in graduate education.[4] Similarly, the Indian Council of Agricultural Research (ICAR) comprises 101 institutes and 71 agricultural universities.[5] In all these models of successful NARES, governments led the way with funding that enabled the establishment of the institutions and development of policies and legislation that provided the enabling environments and ensured sustainability. Moreover, the enabling environments permitted engagement of multiple stakeholders, especially the private sector, which, in turn, facilitated various partnerships among private and public entities.

Neglected and underutilized species

In spite of the successes of the Green Revolution, the CGIAR and NARES, the diversity of food production systems narrowed considerably, to the extent that in many cases food production has become unsustainable. This is exemplified by there being only nine crops (maize, rice, wheat, potato, soybean, cassava, oil palm, sugar beet and sugar cane) that account for over 66 percent of the globe's entire crop production.[6] However, globally, there are almost 400 000 vascular plant species (Royal Botanic Gardens, 2016), of which about seven percent are edible (Food Plants International Database).[7] Furthermore, a little over 6 000 species (or 22 percent of edible plant species), have been actively cultivated for human consumption according to Mansfeld's World Database of Agriculture and Horticultural Crops.[8] Global agricultural and food systems might advantageously tap into the spectrum of neglected and underutilized species (NUS), those plants with prospective value as crops but which have been largely neglected by agricultural researchers, plant breeders, seed companies and policymakers and which currently remain wild or semi-domesticated and are usually not commercialized. Such species include thousands of domesticated, semi-domesticated and wild species of grain crops, roots and tubers, fruits and nuts, vegetables, legumes, spices, condiments and auxiliary plants (Padulosi *et al.*, 2013). The International Network of Food Data Systems (INFOODS) list of underutilized species contributing to the nutritional indicators for biodiversity, maintained by FAO, provides a catalogue of more than 1 000 unique NUS by the countries where they are found.[9]

The diversification of cropping systems, through the increased cultivation of NUS, could enhance the resilience of production systems – especially to the shocks from the effects of climate change (abiotic), including drought and flooding, and from new strains and biotypes of pests and diseases (biotic). This is because the more diverse a system, the less likely that it succumbs uniformly to a particular biotic or abiotic stress. To increase the cultivation and consumption of NUS, perceptions about them must be changed (Hughes and Ebert, 2013; Ebert, 2014). Other constraints that need addressing include the strengthening of human and institutional capacities, especially for better directed research and development activities, in particular for the development of well adapted and nutrient-dense crop varieties. It is also important to increase the availability of quality seeds and planting materials, to improve extension services, and to strengthen advocacy efforts to create an enabling policy environment for enhancing NUS at country level.

[2] https://www.embrapa.br/en/web/portal/embrapa-in-brazil

[3] http://www.caas.cn/en/about_caas/basic_facts/index.html

[4] http://www.catas.cn/EN/contents/1262/109161.html

[5] https://icar.org.in/content/about-us

[6] http://www.fao.org/faostat/en/#data/QC/visualize

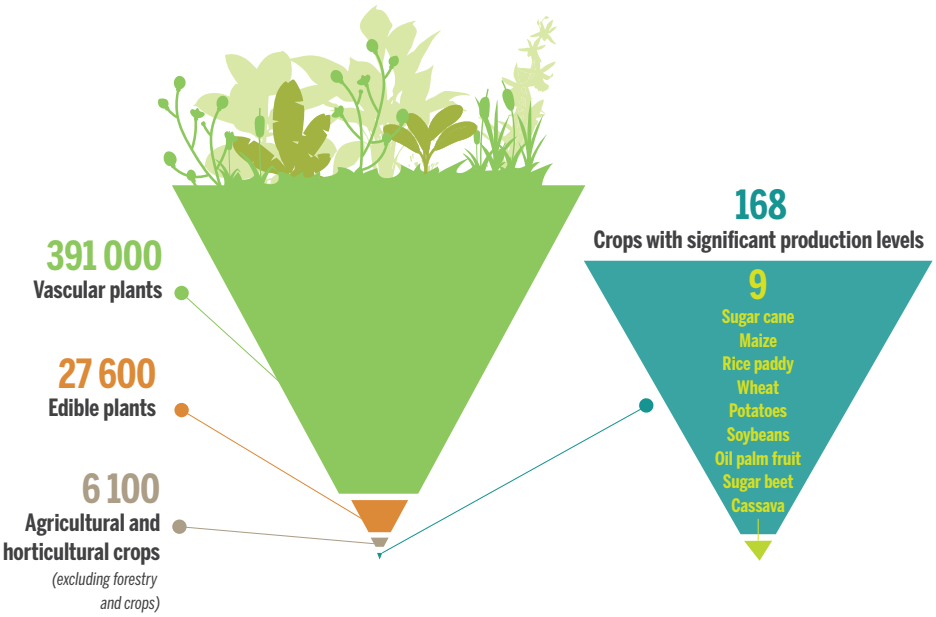
[7] http://foodplantsinternational.com/plants

[8] http://www.re3data.org/repository/r3d100010097

[9] http://www.fao.org/infoods/infoods/food-biodiversity/en

The ensuing research and development endeavours could benefit from of the recent rapid advances in molecular genetics and the more recent suite of genome editing techniques. In addition to the specific references to NUS in the Second GPA, there are other endeavours that represent steps towards the mainstreaming of NUS. These include the NUS Community a web portal,[10] that is dedicated to providing support tools for research on, and promotion of, the use of NUS and the FAO Future Smart Food (FSF) Initiative (FAO, 2018), which aims, among other things, to promote the widespread cultivation and consumption of NUS as means to improved nutrition and enhanced productivities and resilience of agricultural and food systems. FSF promotes NUS that are nutrition-dense, climate-resilient, economically viable and locally accessible. There is also the Crops For the Future (CFF), based in Malaysia that conducts research on underutilized crops and has developed a Global Knowledge Base to support value chains under current and future scenarios.11 The African Orphan Crop Consortium (AOCC), a collaboration between the African Union Commission, African governments (through the New Partnership for Africa's Development or NEPAD), international organizations (FAO and the United Nations Children's Fund, UNICEF), companies (Google, Mars), scientific bodies and civil society organizations, represent another example.[12] Innovatively, the AOCC aims to sequence the genomes of 101 crops and runs the African Plant Breeding Academy from the Nairobi, Kenya campus of the World Agroforestry Centre. The use of global plant diversity for food is detailed in Figure 2.

FIGURE 2: **Use of global plant diversity for food**



Source: Furman *et al.*, 2021. Globally, there are almost 400 000 plant species out of which humans have consumed less than 30 000 (or barely 7%) as food. Fewer still, a little over 6 000 plants (or 22% of edible plants), have been cultivated for producing food. Of these, fewer than 200 plants constitute the main sources of global food production with only nine of them (sugar cane, maize, rice, wheat, potatoes, soybeans, oil palm fruit, sugar beet and cassava) accounting for over 66% of all crop production.

A framework for action

The Second GPA, which was developed under the auspices of the FAO Commission on Genetic Resources for Food and Agriculture is the internationally agreed framework for the conservation and sustainable use of PGRFA.[13] It was endorsed by the FAO Council in 2011 and stipulates 18 priority activities for conserving and using PGRFA sustainably (Box 1) – which aims at the timely availability to farmers of sufficient quantities of quality seeds and planting materials of the most suitable crop varieties. The Second GPA therefore serves as the template for FAO's engagement with member countries for the conservation and sustainable use of PGRFA, while the *World Information*

[10] http://www.nuscommunity.org/about-us/the-nus-community

[11] http://www.cffresearch.org

[12] http://africanorphancrops.org

[13] http://www.fao.org/cgrfa/en

and Early Warning System on PGRFA (WIEWS)[14] serves as a platform for reporting on progress made by countries towards the implementation of the Second GPA and Target 2.5 of the Sustainable Development Goals.

Conservation of PGRFA

Countries should safeguard the full range of diversity of PGRFA, characterize their genetic variation, evaluate the variants for agronomic performance and publish the associated data. PGRFA are conserved in three main ways:

- *In situ* conservation (Priority Activities 1, 4 and 8 of the Second GPA). CWR and wild food plants are conserved in their natural habitats. CWR, especially as they continue to evolve adaptive traits, serve as rich repositories of heritable characteristics (and the allelic variation) for breeding improved crop varieties. Moreover, wild food plants, also found in natural habitats, are important sources of micronutrients and provide livelihoods for millions of people, especially small-scale farmers. A valuable tool to assist in conservation of PGRFA in their natural habitats is the *Voluntary Guidelines for National Level Conservation of Crop Wild Relatives and Wild Food Plants* (FAO, 2017b).
- On-farm management (Priority Activities 2, 3, 10 and 11 of the Second GPA). PGRFA found on-farm as part of production systems, including farmers' varieties/landraces, represent valuable intra- and inter-specific diversity. When diverse, they confer much needed resilience to shocks experienced by cropping systems. The *Voluntary Guidelines for the Conservation and Sustainable Use of Farmers' Varieties/Landraces* (FAO, 2019a) aim at supporting national efforts to maintain or enhance on-farm diversity of PGRFA.
- *Ex situ* conservation (Priority Activities 5 to 8 of the Second GPA). This refers to the safeguarding of PGRFA, under partially or wholly controlled conditions, in specific genebank facilities or areas outside their natural habitats. Genebanks are integral to conserving and facilitating access to the germplasm accessions they store and the associated information that is important in research and improvement. In addition, genebanks follow protocols that ensure the viability of the conserved germplasm, which is characterized according to universally agreed descriptors, and the associated data that are easily retrievable from web-based databases. Countries and stakeholders use the *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (FAO, 2013) as a reference for genebank workflow. Currently, there are over 5.4 million accessions conserved under medium- and long-term conditions in 103 countries and 17 regional and international centres. IRRI, for instance, conserves nearly 132 000 unique accessions of rice in its genebank and CIMMYT conserves 32 217 and 161 708 accessions of maize and of wheat, respectively.[15]

Advances in science and technology affect the scale and efficiency of PGRFA conservation and the ease and feasibility of access to them. The use of *in vitro* culture for the conservation of germplasm as plantlets and also the use of cryopreservation, are well documented. The appropriate protocols are also adopted in many genebanks worldwide, especially to conserve species that produce recalcitrant seeds or that reproduce asexually. Increasing capacities in information technology also enable the safeguarding and dissemination of characterization and evaluation data, thereby making it easier to locate and use particular germplasm accessions.

The greatest advances in the recent past, however, have been in molecular biology, which coupled with advances in engineering and computer science, have resulted in next generation sequencing (NGS) and advanced bioinformatics capabilities. Increasing human and institutional capacities, coupled with significantly lowered costs, have made it possible to generate,

[14] http://www.fao.org/wiews/en

[15] http://www.fao.org/wiews/en

store, analyse and share – sometimes publicly – substantial amounts of DNA sequence data. Advances are such that entire genomes can be sequenced and the resulting data curated at vastly reduced expense compared with 20 years ago. With this enhanced facility, genebanks are often able to sequence complete genomes of germplasm accessions as a characterization technique. This is termed genotyping by sequencing (GBS).

The nucleotide sequence data resulting from these activities fall under the broad category of digital sequence information (DSI). This has become a topical issue that is addressed in international forums such as the Convention on Biological Diversity (CBD) and in FAO through its Commission on Genetic Resources for Food and Agriculture and the International Treaty for Plant Genetic Resources for Food and Agriculture (Treaty). The ownership of the sequence data of the genetic resources can, however, be contentious, principally because of the advances in synthetic biology. Although a universal definition for this branch of science has not been agreed on, it is "the *de novo* synthesis of genetic material and an engineering-based approach to develop components, organisms and products" (Secretariat of the CBD, 2015). This has raised biopiracy concerns that whole organisms or individual genes (especially for commercial products) could be created from DSI in the laboratory (Servick, 2016) using synthetic biology. This could obviate the need for the plant from which such products would normally be synthesized. DNA sequences are created from scratch and sequences are designed to create an organism that did not previously exist, such as Synthetic Yeast 2.0[16] and *Mycoplasma mycoides* JCVI-syn1.0 (Gibson *et al*., 2010). Therefore, using computers and laboratory reagents, organisms capable of novel processes, such as biofuel production or production of precursors for medical drugs, might be produced *de novo*. Examples of current progress in this field include production of artemisinic acid, an anti-malarial drug, which is normally extracted from the plant *Artemisia annua*.

[16] http://syntheticyeast.org/sc2-0

Plant breeding

(Priority Activities 8 and 9 of the Second GPA)

In order to meet increasing demand for food, it will be necessary that national plant breeding efforts continue to be directed to develop improved crop varieties that are adapted to the environments in which they are to be grown, in terms of agro-ecologies and production systems, and which satisfy user requirements. Genetic gains, the improvements in desired traits in offspring relative to their parents, represent the most sustainable means for developing high yielding crop varieties that can be grown in intensified sustainable crop production systems. Therefore, the potential inherent in the genetic profiles of PGRFA has to be realized through the application of up-to-date scientific and technological tools and procedures.

The ability to develop progressively improved crop varieties depends on the availability of exploitable heritable variation. Advances in science and technology are making it increasingly possible to identify, isolate, characterize, modify, induce and transfer the heritable factors that control the traits of interest. In situations where crossing barriers prevent the transfer of desirable traits through cross fertilization, cell biology techniques such as embryo rescue – as was the case with the very successful NERICA rice varieties – are used to facilitate hybridization (WARDA, 2001; 2002).

A major contribution to the science of plant breeding is the creation through artificial means of novel heritable variations that are subsequently exploited in breeding new crop varieties. Induced mutagenesis, using ionizing radiation or chemicals, is used to create novel heritable variations. The Mutant Varieties Database (MVD) of the Joint Food and Agriculture Organization and the International Atomic Energy Agency Centre for Nuclear Techniques in Food and Agriculture has data on over 3 300 induced mutant crop varieties that have been released for cultivation in various countries (IAEA, 2020).

Advances in molecular genetics have also made it possible to bring together hereditary materials from more than one source artificially in the laboratory to

produce new DNA sequences that express novel traits. Genetic modification (GM) or genetic engineering is one such recombinant DNA technique. It is estimated that 70 countries have approved 425 GM events in 32 plants for commercialization, planting or importation as food or feed (ISAAA, 2018).

More recently, genome editing (or gene editing), the term that refers to a new set of techniques for making precise changes to the genetic constitution of a living organism (Hua *et al.*, 2019; Kim and Kim, 2019), are also being used to generate heritable variation artificially. The most commonly used of these new techniques are zinc-finger nucleases (ZFNs), TAL (transcription-activator-like) effector nucleases (TALENs) and CRISPR (clustered regularly interspaced short palindromic repeat) (Gupta and Musunuru, 2014; Hsu *et al*., 2014; Trevino and Zhang, 2014; Jiang and Marraffini, 2015; Sternberg and Doudna, 2015; Langner *et al*., 2018). CRISPR/Cas9 and other CRISPR/Cas systems, the most commonly used of these techniques (Mao *et al*., 2019), has been used to modify the traits of many plants, including the model plants *Arabidopsis* and *Medicago truncatula* and other plants from various genera, including rice, wheat, maize, soybean, sorghum, cotton, rapeseed, barley, tobacco and its close relatives (*Nicotiana benthamiana* and *N. attenuate*) tomato, potato, sweet orange, cucumber, wild cabbage, a wild legume (*Lotus japonicus*) lettuce, common liverwort, petunia, grape, apple, cassava, and watermelon (Waltz, 2016a; Bomgardner, 2017; Manghwar *et al.*, 2019). The modified traits included enhanced vigour and improved yield, herbicide tolerance, resistance to diseases, dwarf stature and altered quality attributes — such as increased grain protein digestibility and reduced amylose content – while other modifications included albinism, alteration of leaf morphology and changes to days to flowering. While most of these modifications have been proofs of concept, the waxy corn (with reduced amylose and increased amylopectin contents) developed by the multinational seed company DuPont Pioneer, could be commercialized by 2021 (Waltz, 2016b; Bomgardner, 2017).

Delivery of quality seeds and planting materials

(Priority Activity 12 of the Second GPA)

The ready access to quality seeds and planting materials of a range of farmer-preferred crop varieties is a prerequisite to realize the potential represented by plant breeding for enhanced productivity. This requires various types of seed enterprise and community-based production and distribution systems and the institutional procedures to ensure production of suitable quality material. Both the public and private sectors are very important, and usually play complementary roles because both informal and formal seed delivery systems need to function efficiently and effectively for farmers to benefit from plant breeding. Government agencies, research and breeding institutions, seed enterprises and farmer- and community-based organizations typically cooperate in the development and operation of a sustainable seed sector value chain. The requisite activities depend on significant skills, and the FAO Seeds Toolkit (FAO, 2019), which targets small-scale production systems serviced by community-based small- and medium-scale enterprises, can be used to enhance such skills.

National efforts continue to require significant support in strengthening institutional and human capacities in terms of science, technology, policy development and formulation of legislative instruments. Efforts usually target the development, implementation, harmonization and revision of national and regional seed policies, laws and regulations. Typically, the instruments govern variety registration and release, plant variety protection, seed production, certification, packaging and labelling, marketing and biosafety. The voluntary guide for national seed policy formulation is a useful reference for countries seeking to provide an effective enabling environment for seed delivery (FAO, 2015b).

Building sustainable institutional and human capacities

(Priority Activities 13 to 18 of the Second GPA)

The continued strengthening of human and institutional capacities is essential for all the Priority Activities of the Second GPA. While the specific interventions will depend on the particular needs and circumstances of each country, and for the particular module of the PGRFA management continuum that is targeted, the Guidelines for Developing a National Strategy for Plant Genetic Resources for Food and Agriculture are helpful for countries seeking to strengthen national programmes and foster synergies among the stakeholders (FAO, 2015a). Priority activities of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture are provided in Table 1.

TABLE 1: **Priority Activities of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture**

Main group	Priority Activity
In situ conservation and management	› Surveying and inventorying PGRFA › Supporting on-farm management and improvement of PGRFA › Assisting farmers in disaster situations to restore crop systems › Promoting *in situ* conservation and management of CWR and wild food plants
Ex situ conservation	› Supporting targeted collecting of PGRFA › Sustaining and expanding *ex situ* conservation of germplasm › Regenerating and multiplying *ex situ* accessions
Sustainable use	› Expanding the characterization, evaluation and further development of specific subsets of collections to facilitate use › Supporting plant breeding, genetic enhancement and base-broadening efforts › Promoting diversification of crop production and broadening crop diversity for sustainable agriculture › Promoting development and commercialization of all varieties, primarily farmers' varieties/landraces and underutilized species › Supporting seed production and distribution
Building sustainable institutional and human capacities	› Building and strengthening national programmes › Promoting and strengthening networks for PGRFA › Constructing and strengthening comprehensive information systems for PGRFA › Developing and strengthening systems for monitoring and safeguarding genetic diversity and minimizing genetic erosion of PGRFA › Building and strengthening human resource capacity › Promoting and strengthening public awareness of the importance of PGRFA

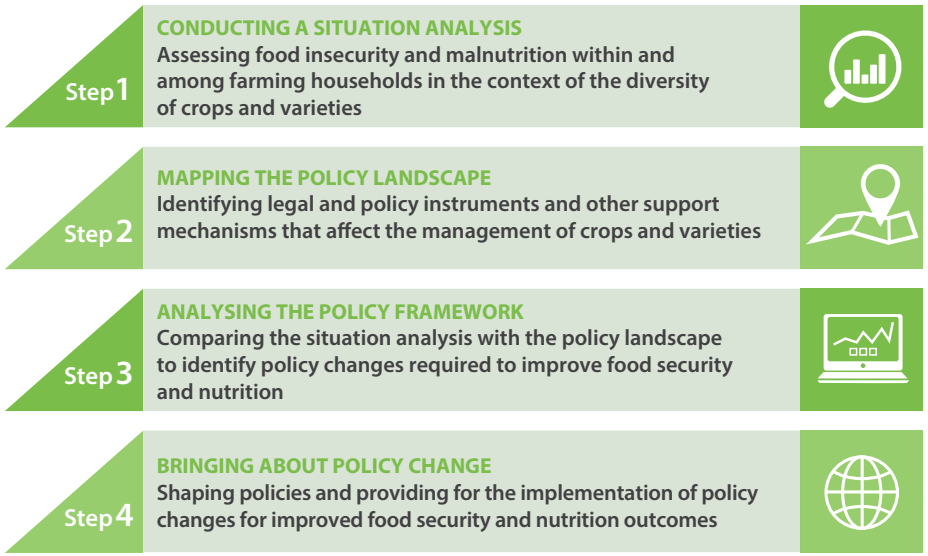
Source: FAO, 2011b.

Stepwise approach

Shaping policies on crops and varieties for better food security and nutrition outcomes

This section provides guidance for policy makers and stakeholders on how to shape policies on crops and varieties that improve food security and nutrition. The information is organized in four steps, which can be regarded as a roadmap through the most important policy options. These are detailed in Figure 3.

FIGURE 3: **Four steps for shaping policies on crops and varieties for better food security and nutrition results**



Step 1 CONDUCTING A SITUATION ANALYSIS

This first step covers analysis of the state of food insecurity and malnutrition within and among farming households in a country, and thus of those who depend on crops for food production and livelihoods. In this context, the state of crops and varieties in terms of conservation of their diversity, innovation and sustainable use is part of the analysis. Before conducting such a situation analysis, it is, however, important to consider whom to include in the process, in order to ensure ownership of the ensuing policy changes among stakeholders. This is in turn is important for policy implementation.

i) Who should be included in conducting a situation analysis to ensure that policy changes will be implemented – and how?

In-country coordination should involve all PGRFA stakeholders, especially those from the ministries of agriculture and the environment, academia, research and development organizations, national crop working groups, civil society, community- and farmer-based organizations. Their representatives would include genebank curators, plant breeders, researchers, wardens of protected areas and farmers. Involvement of the widest possible stakeholder base facilitates priority setting, resource pooling rather than the duplication of efforts, and enhances a sense of ownership and ultimately sustainability of activities.

ii) Identifying the food insecure and malnourished who depend on seeds and planting material for their food and livelihoods

The current food security and nutrition situation in a country can initially be gauged from existing data. The FAO food balance sheets represent a good starting point, providing essential information on a country's food system with regard to domestic food supply, use (including feed and seed) and per capita values for the supply of all food commodities, in terms of energy, protein and fat contents. The FAO food security indicators are another useful source of data, covering country-based data on the four dimensions of food security: availability, access, use and stability. Because these data have been collected on an annual basis since 1999, it is possible to identify trends and developments. The annual FAO report on the state of food security and nutrition in the world, offers further useful data with which to make a broad assessment.

Furthermore, the United Nations Children's Fund (UNICEF) provides country-based data on nutrition for children, through its Multiple Indicator Cluster Surveys, and the WHO has a Nutrition Landscape Information System, which offers country-based data on a range of indicators related to nutrition.[17]

Through these sources it is possible to get an overview of the number of food insecure and malnourished people in a country, the extent to which they are burdened by food insecurity and malnourishment and the trends over time.

For more detailed information, the World Food Program (WFP) publishes Comprehensive Food Security and Vulnerability Analysis reports for many countries. Here regional and demographic differences within the countries are highlighted.[18] Other international organizations and research entities also provide country-based data related to food insecurity and malnutrition, which can be found on the Internet.

Analysing these data, it will normally be possible to establish where the food insecure and malnourished live and whether it is in areas dependent on farming for food and livelihoods. Should data be missing, stakeholders invited to participate in conducting a situation analysis may help generate additional information. It is also useful to try to describe the groups of food insecure and malnourished people according to regions and key characteristics for groups within regions and developments over time. The latter may also help identify emergency situations.

iii) Identifying reasons for food insecurity and malnourishment related to crops and varieties, seed and planting materials

What are the reasons for food insecurity and malnourishment and how is the issue related to crops and varieties, seed and planting materials? As a point of departure, farming communities experiencing food insecurity and malnutrition do not have access to sufficient supplies of food and food items covering the energy and nutrients they need. Reasons may be related to the area of land available for agricultural production, production methods or lack of inputs – including weak purchasing power. Climate change, in terms of droughts, floods, strong winds, increased temperatures, frosts and unpredictable weather/seasons also has an effect on crop production, as do pests and diseases. There is also often neglect and underuse of particular species that could contribute to dietary diversity, income generation, nutrition and food security, particularly during difficult periods. Moreover, preferential incentives for, and investments and emphasis on, solely energy-rich crops could limit the diversity of choice and result in malnutrition.

Lack of quality seeds of preferred crops and varieties may be a reason for food insecurity and malnutrition in itself, but this is often closely related to the issues highlighted above. For example, farmers may lack access to seed and planting material of crops and varieties that are adapted to the effects of

[17] https://mics.unicef.org

[18] https://www.wfp.org/food-security-analysis

climate change, crop pests and diseases or other environmental factors. As a result, farmers may experience crop failures. They may lack access to crops and varieties that are input efficient, being relatively less demanding of expensive external inputs. Not least, growers may lack access to seed of sufficiently nutritious crops and varieties. Such cases represent aspects of seed insecurity and are thus important factors for explaining food insecurity and malnutrition (Sperling and McGuire, 2012).

An important part of the situation analysis is therefore to assess the state of seed insecurity in the country (Box 2). The point of departure for a seed security analysis is the seed systems used by food insecure and malnourished farming communities: essentially the ways in which they obtain seed.

The definition of seed security, as detailed in publications from FAO, provides a useful foundation for formulating policies on the management of crops and varieties for food security and improved nutrition.

Seed may originate from informal or formal sources, and farmers can get seeds from either. Nevertheless, the informal seed sector is by far the largest in most developing countries, often representing 80–90 percent of the total seed stocks. Thus, it is of pivotal importance to understand this system, in order to design policies that can strengthen local seed security.

The formal seed sector provides farmers with seed and planting material of improved/modern varieties resulting from plant breeding, with seed production and marketing following defined standards and regulations normally provided in national legislation. The informal seed sector comprises all the other ways in which farmers obtain seed – from their own harvests, from friends, relatives and neighbours, from local markets or from community seed banks. Seed and planting material may be exchanged, bartered, purchased or received as gifts within the informal seed sector.

There are different forms of interaction between the formal and informal seed sectors. For example, some breeding companies may improve and develop local crop varieties preferred by farmers. Also, participatory plant breeding schemes may have features of both the formal and informal seed sectors. Farmer groups may produce seeds of preferred varieties originating from the informal system, following the system of Quality Declared Seeds (detailed below). Thus, the distinctions between formal and informal seed systems are not always obvious and differences may be gradual (Louwaars and de Boef, 2012). Generally, it is important for farmers to have the opportunity

Box 2 Assessing seed security

Seed security exists when men and women within the household have sufficient access to quantities of available good quality seed and planting materials of preferred crop varieties at all times in both good and bad cropping seasons.

When assessing seed security in a country, four factors are of particular relevance:

- **Seed availability:** sufficient quantity of seed/planting material from all sources within reasonable proximity and in time for planting.
- **Seed access:** farmers can obtain seed/planting material through cash purchase, exchange, loan, barter or gift.
- **Varietal suitability**: the extent to which crop varieties are preferred by farmers (in terms of taste, cooking qualities, storability, fodder potential, income potential) and are adapted to local growing conditions (soil, climate, pests, diseases)
- **Seed quality:** ability of the seed/planting material to germinate and produce healthy seedlings. Attributes include physical purity, seed moisture and presence of diseases.

Source: FAO, 2016: *Seed Security Assessment – A Practitioner's Guide.* Rome.

to switch between sources of seed and planting material, so that if one source dries up, an alternative is available.

iv) Assessment of whether the management of crops and varieties in the country responds to the needs for improved food security and nutrition

In this section, the elements for assessing the fitness of purpose of the PGRFA management continuum are identified. The aim is to determine whether, taken in concert, the conservation of PGRFA (*ex situ*, *in situ* and on-farm) and sustainable use (plant breeding and seed systems) result in crops and varieties that are deployed in sustainable intensive crop production systems to meet the prevailing food security and nutrition requirements. The assessment should, in particular, determine how well the following are conducted:

- *Ex situ* conservation. The targeted collecting of PGRFA, maintenance and expansion of collections, and characterization, evaluation, regeneration, multiplication, safety duplication, documentation and distribution of accessions.
- *In situ* conservation. The safeguarding of, and access to, CWR and wild food plants in their natural habitats and their sustainable use – both directly by farmers and other end-users and for research and development, including pre-breeding and breeding for improved crop varieties.
- On-farm management of PGRFA. The availability and active management of farmers' varieties/landraces in farmers' fields, orchards and home gardens and linkages to their *ex situ* conservation and the promotion of their enhanced use.
- Plant breeding. The applications of the most cost-efficient and validated methodologies to generate well-adapted nutritious and input use efficient crop varieties that are acceptable to farmers and fit into their production systems.
- Seed systems. The evaluation, registration and release of crop varieties and the timely availability, at reasonable prices, of sufficient quantities of quality seeds to farmers through appropriate channels – encompassing the formal and informal systems.

The situation analysis may question components of the continuum of activities that result in crops and varieties in order to assess their contribution to food security and nutrition in the country.

Step 2 MAPPING THE POLICY LANDSCAPE

The purpose with this second step is to provide guidance on how to map and describe the legal instruments and policies relevant to the management and use of crops and varieties for improved food security and nutrition. The focus is on legislation and policies that are targeted towards this aim as well as those that affect such outcomes. The issue of policy coherence in this regard will also be addressed.

i) Mapping the national commitments to international instruments and agreements that focus on and affect the management and use of crops and varieties for improved food security and nutrition

International instruments relevant for the conservation and sustainable use of PGRFA

Most countries have ratified the Treaty and the CBD and have participated in adopting the GPA. Whereas the first two instruments are legally binding, the third is not, but it represents a jointly agreed framework for the implementation of the Treaty. What all three have in common is that they

have the conservation and sustainable use of PGRFA as central objectives, with the fair and equitable sharing of the benefits arising from their use (the CBD is broader in scope). As such they are the key international instruments for providing sound development of the conservation and sustainable use of PGRFA.

The Treaty, developed in harmony with the CBD, sets out that contracting parties shall promote an integrated approach to the exploration, conservation and sustainable use of PGRFA and suggests useful measures as to how this may best be implemented (Art. 5). Contracting parties are obliged to develop and maintain appropriate policy and legal measures that promote the sustainable use of PGRFA (Art. 6), and the Treaty proposes a set of measures towards that end. The contracting parties to the Treaty recognize the enormous contribution that local and indigenous communities and farmers have made, and will continue to make, to the conservation and development of PGRFA, and state that this constitutes the basis of food and agricultural production throughout the world (Art. 9). Against this background, the Treaty provides for the realization of Farmers' Rights related to crop genetic resources. These rights are not defined, but particular measures are proposed relating to the protection of traditional knowledge, the right to participate in the sharing of benefits arising from the use of crop genetic resources and the right to participate in relevant decision-making at the national level. Rights that farmers may have to save, use, exchange and sell farm-saved seed are addressed, but without strict definition.

Under the Treaty, a multilateral system of access and benefit sharing (Multilateral System) was established, through which contracting parties agree to provide facilitated access to genetic resources of sixty-four crops and forages that are crucial for food security worldwide based on a Standard Material Transfer Agreement (the list may be extended). The system applies to those crops and forages that are in the public domain and under the control of the contracting parties. The multilateral system can be seen as the most advanced expression of countries' intentions to cooperate in the management and distribution of PGRFA, and thus in the sustainable use of crops and varieties.

A complementary international agreement is given through the Nagoya Protocol on Access and Benefit Sharing under the CBD. This protocol applies to the remaining crops and varieties that are not covered by the Multilateral System under the Treaty and all other genetic resources covered by the CBD.

The Second GPA, an internationally agreed strategic framework for the conservation and sustainable use of PGRFA, aims at strengthening the implementation of the Treaty. It comprises detailed priority activities for the conservation and sustainable use of PGRFA:

- To achieve ***in situ* conservation and management of PGRFA**, the first priority activity is surveying and inventorying PGRFA. Furthermore, on-farm management and improvement of PGRFA is to be supported. It is also important to assist farmers in disaster situations to restore crop systems. A final priority activity is to promote *in situ* conservation and management of CWR and wild food plants.
- To achieve ***ex situ* conservation of PGRFA**, the first priority activity supports targeted collecting of PGRFA. A subsequent priority is to sustain and expand *ex situ* conservation of germplasm. It is also important to recognize that regenerating and multiplying *ex situ* accessions is crucial for their continued conservation and use.
- To achieve **sustainable use of crops and varieties** some of the priority activities include expanding characterization, evaluation and further development of specific subsets of collections to facilitate use and to promote development and commercialization of all varieties, primarily farmers' varieties/landraces and underutilized species.

For each of these priority activities, detailed recommendations are provided as to how to proceed, including background, objectives, recommendations on policy/strategies, capacity building, research and technology and coordination/administration. The Svalbard Global Seed Vault, as detailed in Box 3, provides an example of international cooperation for conservation of germplasm.

International instruments relevant for crop improvement

The international instruments highlighted above are also relevant for crop breeding. The Treaty provides that the sustainable use of PGRFA may include such measures as promoting, as appropriate, plant breeding efforts which, with the participation of farmers, particularly in developing countries, strengthen the capacity to develop varieties particularly adapted to social,

Box 3

Cooperation works – The Svalbard Global Seed Vault rescued germplasm conserved in Syria

The Svalbard Global Seed Vault holds the world's largest collection of crop diversity. It is a secure facility that can store up to four and a half million samples of crop species and their wild relatives from all over the world. By preserving duplicate samples of seeds held in genebanks worldwide, the vault provides an insurance against loss of crop diversity that can occur for many reasons, including lack of national funding for genebank maintenance and poor management. The vault's facilities are owned by the Norwegian government and operate under a three-party agreement among the Global Crop Diversity Trust, the Government of Norway and the Nordic Genetic Resource Centre (NordGen). Materials deposited in the vault are owned by the depositors and only they can retrieve the materials when they require to do so.

For the Syrian Arab Republic, the vault was a salvation. Before the Syrian war, samples of important crop varieties for dry areas had been conserved at the International Center for Agricultural Research in Dry Areas (ICARDA), which was headquartered in Aleppo, Syria. ICARDA, in turn, deposited security samples of these varieties in the Svalbard Global Seed Vault. The Syrian civil war, which began in 2011, and is ongoing, led to the evacuation of the ICARDA headquarters, the cessation of crop breeding programmes and loss of access to the genebank. In 2015, however, 38 073 seed samples from ICARDA, stored in the Svalbard Global Seed Vault, were repatriated to ICARDA's research centres in Lebanon and Morocco. A second repatriation of 52 351 ICARDA genebank accessions occurred in 2017. Faba bean, wild barley, pea, vetch, forage and range species and cultivated and wild chickpea were sent to Lebanon, and bread wheat, durum wheat, barley, chickpea and lentil to Morocco. Because the conditions in the Syrian Arab Republic remained uncertain, scientists from ICARDA regenerated the material and resumed their research on these crops in more secure areas, preparing a better future for Syria when it becomes possible to work there again.

"We are so happy that we were foresighted enough to secure our valuable seed collection in Svalbard, and that we are able to get viable seeds of good quality back now", said Dr Ali Shehaded, Rangeland and Pasture Germplasm Curator of ICARDA, at Svalbard as the seed samples were sent back to ICARDA.

Source: The Global Crop Diversity Trust: https://www.croptrust.org/press-release/vault-continues-prove-value-world

economic and ecological conditions, including those in marginal areas (Art. 6.2.c). Other measures address how to broaden the genetic base of crops and increase the range of genetic diversity available to farmers, and to promote the expanded use of local and locally adapted crops, varieties and underutilized species (Art. 6.2.d and 6.2.e). Also, countries may review, and, as appropriate, adjust their breeding strategies (Art. 6.2.g). The Multilateral System for Access and Benefit Sharing is a crucial instrument for crop breeding because it enables facilitated access to seed and planting material on a global basis.

The CBD may affect breeding strategies through its arrangements for access and benefit sharing. Because access to seed and planting material of crops that are covered under the Nagoya Protocol is to be approached on a bilateral basis between users and providers, and without a standard material transfer agreement as under the Treaty, it is more demanding. Plant breeding typically requires access to a broad range of varieties and breeding lines, and thus negotiating bilateral agreements for each may not be feasible. Therefore, the requirements under the Nagaya Protocol may appear as a limiting factor for plant breeding but do cover those PGRFA not covered by Annex 1 of the Treaty.[19]

As described above, sustainable use of PGRFA is one of the principal priority activities of the Second GPA. It covers a range of activities, of which support for plant breeding, genetic enhancement and base broadening is central. Furthermore, the priority activity of promoting the diversification of crop production and the broadening of crop diversity for sustainable agriculture is relevant in this context. The Second GPA offers detailed recommendations on how such activities may be developed.

Other international agreements relevant for crop breeding include the Convention of the Union for the Protection of New Varieties of Plants (UPOV) and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) of the WTO. UPOV aims at protecting new varieties of plants with plant breeders' rights. TRIPS regulates internationally various forms of intellectual property rights, including patents and *sui generis* systems of intellectual property rights. Countries may also be parties to regional or bilateral trade agreements with provisions that require them to become members of UPOV and/or the WTO if they are not already members. What these types of agreements have in common is that they were developed out of a different rationale and with other objectives. Intellectual property rights are normally aimed at stimulating modern plant breeding through safeguarding the rights of plant breeders and patent holders.

A key difference between plant variety protection and patents is the breeders' exemption in plant variety protection. Breeders may use protected varieties for developing further varieties provided that the new varieties are not essentially derived from the original variety. This may be seen as a type of open source system as compared with patents, where there is no breeders' exemption. Access to protected varieties and breeding lines is crucial for the further development of plant breeding. This is why patents on plant varieties or on parts or components of plants or processes in this regard may constitute barriers to further plant breeding.

Depending on their scope and provisions, intellectual property rights limit farmers' possibilities to save, use and exchange seed of protected varieties. In developing countries, legislation on plant variety protection often includes farmers' privilege, enabling small-scale farmers to save and use seed on their own landholdings. Other countries allow the exchange of such seed among farmers, and in a few countries also selling of farm-saved seed from protected varieties is allowed among farmers, provided it is not sold under the label of the protected variety. Farmers' seed systems tend to be a mixture of commercial and of local varieties, and these informal systems provide the great majority of seed used by small-scale farmers in developing countries. It

[19] https://www.cbd.int/abs/doc/protocol/factsheets/policy/ABSFactSheets-Agriculture-web.pdf

is therefore important to formulate legislation on plant breeders' rights that takes into account farmers' needs.

Scientific advances have enabled the use of recombinant DNA methodologies through genetic engineering to generate novel crop varieties, genetically modified organisms (GMOs), with improved nutritional qualities and resistances to abiotic and biotic stresses. However, despite the Cartagena Protocol on Biosafety of the CBD – internationally agreed to ensure safe use in terms of human and animal health and the environment – adoptions have been constrained by several factors. These include national and regional policies and legislation that forbid their cultivation or trade. The polarized positions, that for instance pit civil society and the environmental lobbies against scientists and industry, may have been even more important in curtailing the contributions of GMOs to food security and nutrition than intellectual rights protection regimes and the costs of implementing stringent biosafety frameworks.

Current trends suggest that the adoption of the products of the more recent genome editing (or gene editing) techniques, in particular CRISPR-Cas might be constrained by the same controversies (UNEP, 2019; Zaidi *et al.*, 2019). There is as yet no internationally agreed regulatory mechanism or even a consensus as to whether genome edited organisms are GMOs.

International instruments relevant for the delivery of quality seed and planting materials

The Second GPA has a priority activity supporting seed production and distribution, the objectives of which are to increase the availability of quality seed of a wider range of plant varieties, including improved and farmers' varieties/landraces and to contribute to the maximization of agro-biodiversity and productivity. Furthermore, the priority activity aims at improving the complementarity of seed production and seed distribution in the public and private sectors as well as between different seed systems. It is also an objective to develop and expand viable local level seed production and distribution systems for varieties and crops that are important to farmers, including small-scale farmers. In this context, the priority activity aims at making new crop varieties available to farmers and to make suitable germplasm stored *ex situ* available for multiplication and distribution to farmers to fulfil their needs for sustainable crop production. For this purpose, the Second GPA provides for reviewing seed regulatory frameworks that facilitate the development of seed systems and harmonization at regional level, taking into account the specificities of different seed systems.

Bilateral and/or regional trade agreements referred to above sometimes provide for seed legislation aimed at regulating variety release and seed marketing legislation. Seed legislation is formulated to safeguard the quality of crop varieties and the seed and propagation material that is offered in the market. Dependent on its scope and provisions, seed legislation may impose limitations on selling seed of landraces and farmers' varieties, and in such cases it may be detrimental to the objectives formulated in the Second GPA on the priority activity referred to above, of supporting seed production and distribution. A recent study of status and trends for seed policies and laws (CGRFA-17/19/9.3) found that many countries exempt specific practices such as seed sales among farmers from their seed legislation. Other countries only exempt non-commercial seed exchanges or barter arrangements from their seed laws. Some countries exempt informal seed sales while others regulate them. The Second GPA provides important guidance as to how seed legislation may be formulated to accommodate its objectives.

ii) Mapping national legislation focusing on, or affecting, the management and use of crops and varieties for improved food security and nutrition and the state of implementation

Even though most of the international agreements addressed above are legally binding, many of their provisions are loosely formulated, offering different options for implementation. When mapping the national legislation, an analysis of compliance with the international commitments is important. The overarching aim of the analysis is nevertheless to establish whether the laws and regulations in the country contribute to the management of crops and varieties for food security and nutrition.

Legislation on PGRFA

A country may have legislation on biological diversity and genetic resources, on protected or conservation areas and/or generally on nature protection. Within this area there may be provisions on the conservation and sustainable use of PGRFA. Such provisions may promote the more comprehensive and systematic conservation and sustainable use of biodiversity and genetic resources and provide for ways and means to achieve that, including the institutional framework established for implementation. There may also be legislation implementing the Multilateral System of Access and Benefit Sharing under the Treaty and the Nagoya Protocol of Access and Benefit Sharing of the CBD or other regulatory transactions for genetic material or bioprospecting in other ways. In this context the protection of traditional knowledge may be addressed.

A further set of laws and regulations that may be identified, address farmers' and indigenous peoples' rights and community rights. They are often derived from the Treaty and the CBD, or from other international enactments. Such legislation may be part of broader sets of legislation or it may be independent. This normally regulates farmers', indigenous peoples' and communities' rights related to genetic resources, including to seed and planting material, and associated traditional knowledge.

Legislation related to plant breeding

Many countries have legislation on plant variety protection, securing plant breeders' rights. Some developing countries joined the Union for the Protection of New Varieties of Plants and legislate in line with the UPOV Convention of 1991. Other countries have chosen a *sui generis* system adapted to the specific circumstances and needs in a country. This is usually more liberal with regard to informal seed systems and farmers' customary practices of saving, using, exchanging and selling seed. Even though such legislation is not in line with the requirements of UPOV, both categories of legislation are in line with TRIPS, which requires plant variety protection for countries to become members of the WTO while allowing for effective *sui generis* systems (Art. 27.3.b of the TRIPS Agreement). Countries may also have patent legislation, which is the strongest form of intellectual property protection. National legislation on patents differs with regard to plants. Some allows patenting of plants or their parts and components and/or processes leading to specific products from plants or to the plant as a whole. Some laws do not allow patents on crop varieties, whereas others do, thus enabling double protection of plant varieties with both plant breeders' rights and patents.

Legislation related to the delivery of quality seed and planting material

Variety release, seed quality control and seed marketing legislation provide assurance to farmers of the quality and varietal identity of seed and planting material. Seed legislation therefore usually provides for some forms of inspection and testing procedures that aim to assure high seed quality and the presence of specific traits and performance. Seed legislation also aims to support seed producers and vendors by establishing governance mechanisms for the sector, which typically include the enforcement of fair competition. Seed legislation normally regulates the formal seed system. Because countries revise their seed laws in many parts of the world, to

harmonize them with regional and international standards, and enhance trade in seeds, concerns have been raised over the impact such harmonization may have on the exchange of seeds and thereby the diversity of farmers' varieties and landraces grown in farmer fields. As highlighted in a review of the status and trends of seed policies (CGRFA-17/19/9.3), stringent and cost-intensive registration procedures for seed producers may also restrict the number and diversity of seed producers, including farmers' groups or local enterprises that could otherwise participate in providing good quality seeds. Such conditions may affect the range of actors receiving official recognition and support, and ultimately the diversity of crops and varieties produced and promoted through these channels. Alternative quality assurance schemes, such as Quality Declared Seed, have therefore been devised, especially in developing countries, to facilitate a more decentralized and diverse seed sector, potentially including farmers' seed groups that multiply locally popular varieties.

iii) Mapping national policies, strategies, plans and standards focusing on, or affecting, the management and use of crops and varieties for improved food security and nutrition, and the state of implementation

National policies, strategies, plans and standards represent the more detailed instruments with which to ensure the contribution of crops and varieties to food security and nutrition.

- **Conservation and sustainable use of PGRFA:** A country may have a national strategy, programme or action plan for PGRFA, which may address ways and means to promote conservation and sustainable use. In addition, there may be instruments to promote the maintenance of natural habitats of CWR and wild food plants. There may also be national genebank standards. Some countries also have instruments that promote community seed banks, seed savers, and other groups or organizations that promote the diversity of crops and varieties. These are normally part of a broader set of national policies, strategies or plans.
- **Crop improvement:** A country may have a national plant breeding programme to promote the development of crops and varieties, or more decentralized plant breeding programmes in regions of the country. There may also be support plans.
- **Delivery of high quality seed and planting material:** A country may have a national seed policy, which normally promotes the availability and distribution of high quality seed of commercial crop varieties within the formal seed system, but which may also be formulated in a way that allows, exempts or stimulates farmers' groups, organizations and enterprises to contribute to the seed market. The national seed policy may contain protocols or standards on quality declared seed and planting material.

When the policy landscape has been mapped as suggested above, it will be useful to assess the coherence between the different legislative and policy instruments with regard to promoting the contribution of PGRFA to improved food security and nutrition. Do all the instruments work towards the same end or are there discrepancies? Further guidance in this regard may be found in step 3.

It is also useful to place the policies, strategies, plans and standards referred to above in the larger context of agriculture and food policies, in order to identify how different instruments can reinforce one another.

Step 3 ANALYSING THE POLICY FRAMEWORK

This step is devoted to comparing the situation analysis from step 1 with the policy landscape from step 2 in order to identify whether the legislation and policies respond to the needs among the food insecure and malnourished. Step 3 is designed to guide policymakers and stakeholders in identifying gaps and needs, and the policy changes required to improve food security and nutrition by using the potential of crops and varieties.

In analysing gaps and needs, and identifying potential policy changes, enabling environments are regarded as points of departure, following the continuum of activities required to enable the use of crops and varieties for food security and nutrition, as presented in the background to this policy guidance note.

i) An enabling environment for the conservation and sustainable use of crops and varieties

Because conservation and sustainable use of crops and varieties constitute the basis for seed security among farmers and for the future of farming, an enabling environment is crucial.

National legislation, policies and strategies targeted at the conservation and sustainable use of crop genetic resources and on the maintenance of natural habitats of wild crops and food plants tend to be in line with requirements in this regard and are often well formulated. However, due to limited implementation, their objectives are often not met. This may be for numerous reasons, some technical and others financial, or may be due to a lack of political will. The GPA on PGRFA offers a set of priority activities that may be useful to fill gaps and needs in this regard. Furthermore, an important tool from the FAO is the *Guidelines for Developing a National Strategy for Plant Genetic Resources for Food and Agriculture* (FAO, 2015a). These guidelines aim at translating the Second GPA for PGRFA into national action and assisting countries in implementing the Second GPA in harmony with other relevant national and international commitments. Being aware of each country's needs, capacities and constraints, national strategies for PGRFA should identify a national vision, goals and objectives, and the corresponding plan of action, including responsibilities, resources, and timeframes for activities. Another useful tool is the *Voluntary Guidelines for the Conservation and Sustainable Use of Farmers' Varieties/Landraces* (FAO, 2019a), which outlines the process for preparing a National Plan for Conservation and Sustainable Use of Farmers' Varieties/Landraces, with the aim of supporting national authorities in developing a systematic approach to the management of these genetic resources. A series of decisions and actions that could be helpful to follow in developing such a plan is outlined. Through a step-by-step approach, these guidelines focus on the common elements that could ensure a systematic, national approach to conservation and sustainable use of farmers' varieties/landraces.

To aid countries in conserving PGRFA found in nature and harnessing the potential, FAO published the *Voluntary Guidelines on National Level Conservation of Crop Wild Relatives and Wild Food Plants* (FAO, 2017b). The guidelines are intended as reference material for national governments in their activities towards conservation and sustainable use, when preparing a National Plan for the Conservation and Sustainable Use of Crop Wild Relatives and Wild Food Plants. The focus is on *in situ* conservation and fostering linkages between *in situ* and *ex situ* conservation, and ultimately towards the use of CWR and wild food plants.

As for *ex situ* conservation, FAO's *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (FAO, 2013) represents a compendium of best practices for safeguarding PGRFA as germplasm collections. The standards for the collection, characterization and evaluation of genebank accessions are also included.

Legislation on Farmers' Rights related to PGRFA, as derived from the Treaty, and instruments promoting community seed banks, participatory plant breeding or variety selection schemes, normally contribute to developing enabling environments for the conservation and sustainable use of crop genetic diversity. Options for encouraging, guiding and promoting the realization of Farmers' Rights at the national level are being developed under the Treaty.

ii) An enabling environment for crop improvement

Crop improvement is crucial to enhance food security and improve farmer livelihoods. The deployment of adapted crops and the development of resilient crop varieties that promise high yield under adverse environmental conditions and minimal input systems is central in this context. This is in turn a means to increase the use of genetic resources and diversity in the crops available to farmers. However, reduction in plant breeding capacity in many countries represents a challenge. There is a serious shortage of plant breeders in both public and private sectors and a declining enrolment in conventional plant breeding courses in agricultural universities, schools and institutions. There is a compelling need to redress this situation as the role of conventional plant breeding in crop varietal development is important.

The Second GPA provides for reduced vulnerabilities by increasing the genetic diversity of production systems and enhancing the availability of heritable variations for use in crop breeding programmes, including through the use of CWR, farmers' varieties/landraces as parents. It also provides for the continued generation of improved varieties to increase the sustainability of agricultural systems, especially their capacity to adapt to environmental changes and to emerging needs. The Second GPA also stipulates the activities to strengthen the capacity of national plant breeding programmes and other sectors and to encourage participatory breeding, which enhances the rate of adoption of new crop varieties.

The FAO publication *Farmer Participatory Plant Breeding* (FAO, 2009), especially through the case studies, may provide further guidance in this regard. The publication provides a comprehensive description and assessment of the use of participatory plant breeding in developing countries. The e-learning course on *Pre-breeding for Effective Use of Plant Genetic Resources* is a capacity building tool covering a range of theoretical and practical topics from the basic concepts and applications of pre-breeding to germplasm distribution and regulatory issues.[20] Its purpose is to improve the effective use in breeding of non-adapted germplasm resources, building a bridge between genebank managers and plant breeders.

If a country has ratified the Treaty and made its genetic diversity and related information about the crops covered under the Multilateral System available through that system, the country participates in benefit sharing by having access to seeds and planting materials from other countries, which is beneficial for crop improvement. Stakeholders from the country may apply to the Benefit Sharing Fund under the Treaty to support farmers conserve and sustainably use crop genetic diversity directly or indirectly.

iii) An enabling environment for the production of good quality seed and planting materials of preferred varieties that may be accessible for small-scale farmers

[20] https://elearning.fao.org/course/view.php?id=493

The availability of, and access to, quality seeds of a diverse range of adapted crop varieties is essential for achieving food and livelihood security and for eradicating hunger, especially in developing countries. Effective seed systems must be in place to ensure that farmers have access to planting materials in adequate quantity and quality, in a timely manner and at reasonable cost. Only in this way will farmers benefit from the potential of both local and improved varieties to increase food production and adapt to climate change. Over the last 30 years, the private agricultural sector has grown significantly in developed and developing countries, but the main focus of its interest has been on high value crops, such as maize, wheat, rice, oilseeds, pulses and vegetables. The expansion of the seed trade over the past decade has been accompanied by the promotion of seed regulatory harmonization at regional and subregional levels. Investment by the public sector in seed production has also decreased significantly in many developing countries, where access to improved varieties and quality seed remains limited.

In many developing countries, farmers' seed systems remain the main sources of seed for local and, in some cases, even improved varieties. Different seed systems often operate side by side with different levels of success depending on the crop, the agro-ecological zone and market opportunities. There is therefore a need to develop integrated approaches that strengthen seed systems and the connections between them in order to ensure the production and distribution of seed of crop varieties that are useful for diverse and evolving farming systems.

The FAO *Voluntary Guide for National Seed Policy Formulation* (FAO, 2015b) explains what seed policies are and how they differ from seed laws. It describes the participatory process of seed policy formulation, the nature and layout of seed policy documents, key elements contained in seed policies and addresses issues involved in their implementation. It is specifically intended for use by policymakers, national seed agencies, civil society, and public and private sector organizations, including national seed associations and farmers' organizations involved in the seed sector. The *Six-Module Seeds Toolkit* (FAO, 2019b) supports practitioners along the entire seed value chain to acquire the knowledge and skills they need to deliver quality seeds and planting materials of well-adapted crop varieties to farmers. It is designed primarily for capacity building activities, especially for small-scale farmers and small- and medium-scale entrepreneurs.

The information contained in Box 4 explains the importance of outreach and promotion in getting new crop varieties into farmers' fields.

Alternative quality control systems in which seed producers are responsible for the quality control without external inspections include Quality Declared Seeds, which has a less intensive third-party inspection regime and lower cost. Quality Declared Seeds systems complement seed certification systems, are most applicable to low input production systems, and are regarded as a transition phase between informal and formal seed systems.

Some countries provide for specific incentives or discounts for small-scale farmers or small-scale farming enterprises, such as lower fees for seed inspection or variety registration. Such incentives may have positive effects on the distribution of diverse crops and varieties. Further development of such incentive structures encourages and promotes the contribution of small-scale farmers and their groups, organizations or enterprises, potentially improving seed security in the country.

The exacting requirements of seed laws, in some instances, may make it difficult for small-scale famers to register as seed sellers or to meet the requirements for seed certification or of varietal registration to be able to sell the seeds of farmers' varieties/landraces. Stringent and cost-intensive registration procedures for seed producers may also restrict the number and diversity of seed producers, including of farmers' groups or local enterprises that could otherwise participate in making good quality seed available. Seed laws should therefore be carefully analysed to ensure that farmers' choices of varieties to grow are not unduly constrained, however inadvertently.

Box 4

Getting new varieties into farmers' fields: the importance of outreach and promotion

Low rates of adoption of new varieties represent one of the main constraints for sustainable increase of production and farmers therefore need to become familiar with new crop varieties and their characteristics if they are to adopt and use them. Farmers in low-income countries in particular may have limited access to meaningful information about new varieties. Conventional extension materials such as brochures and field days may not provide sufficient information for farmers, who may want to observe how a variety performs in their specific location, and at various times throughout the season. Thus, the form of outreach and variety promotion is important. One effective, but simple, approach is to use demonstration plots in multiple locations, enabling many farmers to observe new varieties in-depth and up close, and subsequently make considered decisions about adoption. A European Union funded programme in Mozambique used this approach very successfully to promote new crop varieties, some of them biofortified. Between 2014 and 2019, a total of 1 682 demonstration plots were established, where farmers were able to observe the performance of new varieties from planting to harvest. This led to the adoption of 21 new varieties of six crops.

Number of demonstration plots established

Crop	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	Total
Maize	112	175	198	136	122	743
Cowpea	39	107	123	74	61	404
Bean	30	78	77	75	76	336
Rice		10	2	2		14
Sorghum		16	24	23		63
Soybean			36	32		68
Groundnut			22			22
Pigeon pea			32			32
Total	**181**	**386**	**514**	**342**	**259**	**1 682**

Source: Project GCP/MOZ/111/EC National Programme on Food security – (EU-MDG Initiative – Agriculture, food security, rural development and natural resource management).

iv) An enabling environment for farmers' access to appropriate agricultural technologies to improve the performance of their crops and varieties

Experiences from participatory variety selection and plant breeding programmes in different parts of the world show that they are most successful when combined with the introduction of improved agronomy to boost yields while maintaining soil health, nutrient efficiency and safeguarding resilience to climate change. Local and locally adapted and enhanced varieties of crops combined with low-cost agricultural methods contribute significantly to improved food security and nutrition as well as livelihoods. Stimulating such synergies would be of great value for any policies to improve food security and nutrition.

v) Linkages among the elements of the PGRFA continuum

The analysis of the individual constituent themes of the continuum as presented throughout steps 2 and 3 is as important as determining how well their linkages function. For instance, the analysis should establish how well the conservation of PGRFA supports plant breeding – through the identification and incorporation of useful traits from genebank accessions and CWR. Also, it needs to be ascertained, for instance, whether the seed delivery systems are sufficiently linked with plant breeding so as to get improved crop varieties to farmers efficiently.

Step 4 BRINGING ABOUT POLICY CHANGE

The purpose of this fourth and final step is to provide guidance on how to shape policies based on the analysis above and to develop a framework for implementation towards improved food security and nutrition through using the potential of crops and varieties.

All parts of the continuum of conservation and sustainable use, crop improvement and the delivery of, and access to, quality seeds and planting materials are relevant in this regard because they are interdependent. Countries may choose an integrated approach by seeking to address all components of the continuum, or they may prioritize among the parts of the continuum and the different activities required to promote them. Countries may also plan to address the different parts of the continuum at different points in time over a defined period, in order to accomplish the priority activities required to promote the whole continuum according to available capacity and financial resources. The Second GPA provides useful guidance in this regard. This section highlights central elements.

i) Shaping policies to promote the conservation and sustainable use of crops and varieties

The surveying and inventorying of PGRFA should be considered the first step in the process of conservation and reducing the rate of agrobiodiversity loss, and should be linked to specific objectives and plans for *in situ* conservation, collecting, *ex situ* conservation and use. Local and indigenous knowledge should be recognized as important in surveying and inventorying and should be carefully considered and documented, with the prior informed consent of indigenous and local communities.

On-farm management activities need to be fully integrated into wider conservation and development strategies and action plans. Specific

strategies need to be developed for conserving PGRFA *in situ* and for managing crop diversity on-farm and in protected areas. Special attention should be paid in these strategies to conserving CWR in their centres of origin, centres of diversity and biodiversity hotspots. Governments should consider how production, economic incentives and other policies, as well as agricultural extension and research services, might facilitate and encourage the on-farm management and improvement of PGRFA.

Where appropriate, national policies should aim to strengthen the capacity of indigenous and local communities to participate in crop improvement efforts. Decentralized, participatory and gender-sensitive approaches to crop improvement need to be strengthened in order to produce varieties that are specifically adapted to socio-economically disadvantaged environments. This may require new policies and legislation – including appropriate protection, variety release and seed certification procedures for varieties bred through participatory plant breeding – in order to promote and strengthen their use and ensure that they are included in national agricultural development strategies.

Governments, with the cooperation of farmers' organizations and communities, UN bodies and regional, intergovernmental and non-governmental organizations should establish policies at all levels to allow the implementation of appropriate seed security activities in response to disasters, including the effects of climate change. National genebank collections should be duplicated outside the country, for example at the Svalbard Global Seed Vault. Genebanks and networks should obtain and make characterization and evaluation information available to assist in identifying useful accessions for restoring crop systems, respecting access and benefit-sharing agreements, as facilitated through the Multilateral System of Access and Benefit Sharing under the Treaty.

Governments in collaboration with stakeholders and non-governmental organizations, and taking into account the views of farmers and indigenous and local communities, should include the conservation of PGRFA among the purposes and priorities of national parks and protected areas, in particular for forage species, CWR and species gathered for food or feed in the wild, including in their biodiversity hotspots and genetic reserves.

Governments, international agricultural research centres, non-governmental organizations and funding agencies should provide adequate, appropriate and balanced support for the conservation of vegetatively propagated and recalcitrant seeded plants in addition to the support provided to conserve the seeds of orthodox species. In this regard, botanic gardens and field genebanks should be strengthened in their capacity to conserve important underutilized species. Conserved materials should be replicated and stored in long-term facilities that meet international standards, in accordance with applicable international agreements.

Regeneration and multiplication should strive to maintain the allelic and genotypic diversity and adapted complexes of the original sample. Characterization should be undertaken in conjunction with regeneration without compromising the effectiveness or scientific goals of regeneration. Characterization should be conducted in line with globally accepted standards.

ii) Shaping policies to promote crop improvement

In shaping policies on crop improvement, governments should seek cooperation of relevant international and non-governmental organizations. It is essential to:

- Recognize the importance of providing long-term funding and logistical support to plant breeding and research, pre-breeding, genetic enhancement and base-broadening activities.

- Recognize the importance of providing adequate support for the routine use of novel biotechnology tools, computational biology and information technology in PRGFA management, especially in characterizing germplasm and facilitating the introgression of desired traits into breeding materials.
- Encourage the development of public–private and other partnerships that foster participatory approaches to setting and implementing crop improvement priorities and goals.
- Develop policies and legislation that support participatory breeding, including appropriate regulatory frameworks for varieties developed through participatory plant breeding.
- Encourage the institutionalization of participatory, gender- and youth-sensitive approaches to plant breeding as part of national PGRFA strategies in order to facilitate the adoption of new crop varieties.
- Help improve access by plant breeders to the widest possible genetic diversity in order to identify the traits needed for developing crop varieties adapted to novel climatic conditions.
- When devising national strategies and fostering collaboration, as appropriate, be fully cognizant of the provisions of the Multilateral System of the Treaty, according to which material can be accessed "for the purpose of utilization and conservation for research, breeding and training for food and agriculture."

Governments should also, in collaboration with relevant intergovernmental organizations and in cooperation with crop networks, research institutions, extension agencies, the private sector, farmers' organizations and non-governmental organizations:

- Regularly monitor genetic diversity and assess crop vulnerability.
- Promote policies that support diversification programmes and the inclusion of new species in production systems.
- Promote awareness among policymakers, donors and the general public of the value of diversified production systems.
- Support the management of diversity by breeders and farmers.
- Increase investment in improving underutilized crops and the development and use of traits in major crops that are relevant to human and environmental health and to the effects of climate change.

iii) Shaping policies to promote the delivery of, and access to, high quality seed and planting materials

Governments, national agricultural research centres and seed producers, with support from international agricultural research centres, regional and bilateral cooperation programmes and non-governmental organizations, and taking into account the views of the private sector, farmers' organizations and indigenous and local communities, should:

- Develop appropriate policies that provide an enabling environment for the development of different seed systems, including small-scale seed enterprises. The efforts of governments should focus in particular on the crops and varieties needed by resource-poor farmers, especially women. Such an approach should be complemented by policies that facilitate the development of commercial seed companies to meet the needs of larger scale commercial farmers. Governments should prioritize major and minor crops that are not adequately addressed by the private sector. These policies should be integrated with general agricultural policies.
- Strengthen links among genebanks, networks, plant breeding organizations, seed producers and small-scale seed production and distribution enterprises to ensure wide use of available germplasm.

- Consider seed quality control schemes, particularly schemes that are appropriate for small-scale enterprises and enable them to meet plant health requirements.
- Adopt legislative measures that create adequate conditions for deploying all varieties, primarily farmers' varieties/landraces and underutilized species, in different seed systems, taking into account their specificities.
- Develop subregional and regional agreements that streamline seed quality control, certification, plant quarantine requirements and other standards in order to facilitate the development of cross-border seed trade.

iv) Ensuring coherence and promoting synergies

As this policy guidance note demonstrates, the different elements of the conservation and sustainable use continuum are interdependent. Plant breeding is not possible without access to seed and planting material conserved and sustainably used. The production of quality seed and planting material is not possible without plant breeding. Thus, it is important to ensure coherent legislation and policies that promote the synergies between the different elements of the continuum. For example, seed legislation should serve the requirements for producing quality seed and planting material, without limiting the legal space of farmers to conserve and sustainably use crops and varieties on-farm. Incentive structures should stimulate the conservation and sustainable use on-farm as well as crop breeding and the production of quality seed. There is significant potential for synergies between the formal and informal seed sectors if an enabling environment is developed for that purpose. Such synergies would be beneficial for improved food security and nutrition.

v) Building sustainable institutional and human capacities

It is envisaged that for the foreseeable future, the efforts to conserve and use PGRFA sustainably, especially by developing countries, will continue to benefit from needs-based strengthening of the capacities of personnel and institutions. The continuous upgrading of scientific and technical skills and infrastructure and capacities for developing and implementing policies, strategies and laws is critical for successful outcomes. Considering the interdependence of nations for the optimal conservation and use of PGRFA, the strategic establishment of partnerships and networks at various scales remains imperative. Ideally, capacities should be strengthened across the entire PGRFA management continuum, but in reality the needs are hardly ever uniform. While the improvement of capacities is best considered an overarching theme, as it is applicable across the continuum, training programmes, networks and partnerships and the upgrading of infrastructure are often aimed at particular weaknesses that have been identified.

Public awareness is the key to mobilizing popular opinion and to generating and sustaining appropriate political action nationally, regionally and internationally. Communicating effectively the many benefits that PGRFA can bring to food security and sustainable livelihoods is critical to the success of any conservation programme. Greater efforts are needed to estimate the full value of PGRFA, to assess the impact of their use and to bring this information to the attention of policymakers and the general public. Public awareness and the roles that specific target audiences can play in sustaining plant genetic resources should be considered when developing any PGRFA activity.

National policies and strategies should recognize the role that all PGRFA stakeholders should play in the development of public awareness activities. Governments should recognize and encourage the work of non-governmental organizations in raising public awareness, and efforts should

be made to foster the development of public–private partnerships around public awareness campaigns. The important roles of indigenous and local communities in any *in situ* conservation or on-farm management effort, and their traditional knowledge systems and practices, need to be fully taken into account. Public awareness materials should be produced in appropriate languages to facilitate broad use within countries.

National PGRFA programmes should have a trained focal point for public awareness to work closely with programme managers and develop the necessary tools. They should work with well-known and influential people to increase access to the media and attract attention. Efforts are required to develop and strengthen relationships with the local media and to encourage them to cover PGRFA issues on a regular basis, involving them in communications workshops and meetings to gain a better understanding of the subject area. National PGRFA programmes should draw on public awareness tools and technologies generated at the regional and international levels to use in their own communication efforts.

Awareness of the value of PGRFA and of the role of scientists, plant breeders, farmers, and indigenous and local communities in maintaining and improving these valuable resources should be promoted in schools at all educational levels as well as in specialized agricultural research institutions. Simple, low-cost botanic gardens, arboreta and field genebanks associated with universities, schools and other institutions should be strengthened and encouraged to promote education and public awareness.

vi) Implementing legislation, policies and strategies on crops and varieties

A point of departure for any policy implementation is to make sure that responsibilities have been assigned and that the actors involved know who is responsible to do what and by when. Whereas an overall responsibility for crops and varieties is often assigned to a centre of genetic resources for food and agriculture, a focal point in a ministry of agriculture or an entity assigned with biological diversity, the responsibilities for seed policies, breeding programmes and other aspects of the management of crops and varieties are normally designated to other bodies. This situation may create challenges for implementation in terms of coordination and coherence.

Furthermore, entities responsible for the management of crop genetic diversity often suffer from limited attention from high level political decision-makers and policy areas other than those relating to PGRFA are often prioritized. Communication, awareness raising and capacity building among political decision-makers about the importance of crops and varieties for food security and nutrition is thus central to securing political will for policy implementation.

For coordination purposes, it might be useful to consider establishing an overall responsibility for leadership and coordination at a high level in the ministry of agriculture in order to ensure coherence of the different policies towards enabling and promoting the utilization of crops and varieties for food security and nutrition.

Key stakeholders engaged in the use of crops and varieties for food security and nutrition in developing countries are often civil society organizations, non-governmental organizations, community seed banks and farmer groups of various types. These are often highly experienced and involving them in political decision-making and follow-up is not only important in terms of legitimacy, but also in using available capacity in the country. As experiences from different parts of the world show, such organizations or groups may substantially contribute to policy implementation by shaping and piloting measures that are promoted through the policies. Involving them in policy and implementation processes is not only useful to build on their experiences, but it is also a means

of ensuring their sense of ownership of these processes and thus their motivation to contribute. To ensure policy implementation, it is important to have monitoring systems in place to check, assess and guide implementation. Establishing responsibility for this function is important, and it is important to know who is responsible for doing what and when. A multi-stakeholder reference or resource group is of great value to ensure the broadest possible sharing of, and reflections on, the experiences and to discuss how to proceed. Monitoring progress and adjusting the direction of action is useful at regular intervals. It may also be useful to evaluate the policy implementation after several years to make sure that measures can be taken to adjust the course to reach the goals and targets. Should experiences show that further policy change is required, this represents an opportunity for discussion and to take action if required.

vii) Financing the implementation of policies on crops and varieties

Many good policy and strategy initiatives have been constrained by lack of financial resources. Mapping the sources of financial support for implementing national legislation and policies on the management and use of crops and varieties for improved food security and nutrition is vital for efficient implementation. The following guidance is not exhaustive, but may provide a point of departure for allocating resources.

It is important to demonstrate political will by allocating resources from the national budget. Even if the amount is not sufficient to cover full implementation, it may cover a part and will thus send an important signal for the political priority devoted to implementation. This may in turn trigger financial support from other sources.

At the international level there are various support mechanisms that could be considered. Among them, the Global Crop Diversity Trust may be approached for support to genebank-related policy implementation such as depositing back-up seed accessions from national genebanks in the Svalbard Global Seed Vault. The Benefit Sharing Fund announces project support at regular intervals and applications may cover conservation, sustainable use and innovation in crops and varieties that benefit farmers. The Global Environmental Facility (GEF) has biodiversity as one of its foci, and measures promoting the sustainable use of PGRFA are among the GEF priorities. These include support to establish protection for CWR *in situ* through CWR reserves and projects for *in situ* conservation and sustainable use, through, *inter alia*, farmer management of plant genetic resources in Vavilov Centers of Diversity.

At the bilateral level, collaboration with national development cooperation agencies may be considered. Some countries in Europe have official development assistance (ODA) for projects related to PGRFA among their priorities. Creating a long-term partnership with such agencies could be of great value for policy implementation.

An increasing number of non-governmental organizations in OECD countries are engaged in the conservation, sustainable use and development of crops and diversity for food security and nutrition. They normally support stakeholders from civil society and farmer groups and coordination of such support for grassroots implementation of national policies may be of great value. Some of these organizations may, on occasion, also support government policies more directly.

Public-private partnerships (PPPs) may also be considered. A PPP is a partnership between an agency of the government and the private sector in the delivery of goods or services to the public. Areas of public policy in which PPP have been implemented include a wide range of social services, public transportation and environmental and waste disposal services. To date there is little experience with PPP for using the diversity of crops and varieties for food security and nutrition, but PPP might be used in the future.

viii) Measuring progress

This Policy Guidance Note has used the Second GPA as template for identifying actionable interventions for translating the potentials of plant genetic diversity into improved productivities on farmers' fields and hence improved food security and nutrition Consequently, the *Reporting Format for Monitoring the Implementation of the Second GPA for PGRFA* can serve as an effective monitoring tool.[21] A list of 58 indicators and 48 ancillary questions are used to measure the implementation of the 18 Priority Activities of the Second GPA. Officially designated National Focal Points report on their nation's progress in the WIEWS platform, which is freely accessible.[22]

[21] http://www.fao.org/pgrfa/resources/openDocs/Reporting_Guidelines_2020e.pdf

[22] http://www.fao.org/wiews/en

Concluding remarks

Individual countries and the international development community grapple with the generational challenge of producing more food, especially crops to feed a growing population under increasingly unpredictable climates and without causing further damage to the environment. It is widely agreed that the use of additional arable lands and water resources are impractical solutions to the question of how to produce more food. It is also the case with indiscriminate application of agrochemicals. The implication is that the potential of PGRFA must be realized to generate the necessary increases in food production through enhanced productivity of crops. With the premise that there can be no good crops without good seeds, this Guidance Note sets out the policy and technical options for harnessing the untapped potential of PGRFA to increase productivity on-farm and improve the nutrition of the populace. The case is further made that seeds result from upstream activities, the conservation of PGRFA and plant breeding.

Advances in science and technology, especially in molecular biology, coupled with continuous lowering of costs and stronger institutional and human capacities have enhanced the throughput of these processes and their application. These therefore hold great promise for harnessing intra- and inter-specific variation in PGRFA to address the generational challenge of producing the increasing volumes of food needed with fewer inputs than is currently the case.

However, this optimism is dampened by the realization that the pace of development of enabling policy regimes has lagged behind those for scientific and technological techniques and applications. For instance, there is no agreement on whether or not GMOs released for human consumption or into the environment would be regulated by the Cartagena Protocol on Biosafety. Evidently, developed countries have been taking very different decisions in this regard (Zaidi *et al.*, 2019). At one extreme, the United States of America and Australia rule that products of genome editing require no regulations (Waltz, 2016a; Mallapaty, 2019).[23] At the other end of the spectrum, the European Union and New Zealand impose the same GMO regulations on the products of genome editing (Fritsche, 2018; Callaway, 2018). However, such clarity is lacking for the majority of developing countries that require an increase in food production most and which are particularly vulnerable to the vagaries of climate change. Developing countries are most in need of game-changing innovations that result in sustainable food systems and nutrition. The 2020 Nobel Prize in Chemistry was awarded to the pioneers of CRISPR, Professors Emmanuelle Charpentier and Jennifer Doudna (Ledford and Callaway, 2020). This may provide an impetus for the international development community to arrive at a consensus for taking advantage of this powerful and relatively cheap crop improvement technique to develop and make available to farmers the crop varieties that will contribute to the eradication of hunger and malnutrition as committed to in the Agenda 2030.

It must be stressed however that the genetic gains that come about through crop improvement, and the use of quality seeds and planting materials of well-adapted crop varieties, do not represent a panacea. Genetic gains must be accompanied by improvements in agronomy, soil health, water use efficiency and plant health in order that the potential can be realized and translated into higher productivity on farmers' fields, thereby enhancing food security and nutrition. Moreover, for increased productivity to be sustained over time, the demand for, and use of quality seeds of improved crop varieties must be sustained to foster improvements in the livelihoods of farmers. This underscores the need to improve the value addition post-harvest aspects of crop production, especially processing, packaging, transportation and marketing.

[23] https://www.usda.gov/media/press-releases/2018/03/28/secretary-perdue-issues-usda-statement-plant-breeding-innovation

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