Managing germplasm in a virtual European genebank (AEGIS) through networking

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Abstract:
The importance of Europe as a region of crop genetic diversity and its conservation is analyzed and a brief history of the conservation of plant genetic resources in Europe is presented, in the context of past political and development scenarios. The rather fragmented conservation situation that had evolved and resulted in a significant duplication of conserved germplasm and conservation efforts, diverse conservation standards and a weak coordination between countries and genebanks provided new challenges to ECPGR, a regional plant genetic resources network founded in the early 1980ies to facilitate exchange of germplasm and information among European countries. ECPGR has a strong focus on crop genetic resources conservation, information management and capacity building. In the early 2000s a virtual European genebank (i. e. AEGIS), comprising the unique and important accessions of all plant genetic resources for food and agriculture conserved in Europe, was established. AEGIS operates entirely within the legal framework provided by the International Treaty and the Convention on Biological Diversity and pays due attention to the quality of the conservation efforts. A brief description of the most important management aspects of AEGIS is given. Some controversial and philosophical considerations are presented at the end of the chapter.

Zusammenfassung:
Der Beitrag betont – mit einem Rück- und Ausblick – die Bedeutung Europas als Region genetischer Diversität landwirtschaftlicher Nutzpflanzen und ihrer Erhaltung. Er liefert eine kurze Geschichte der Konservierung pflanzengenetischer Ressourcen. Die eher uneinheitliche Situation resultierte in einer signifikanten Vermehrung von eingelagertem Protoplasma und von Erhaltungsstrategien, in verschiedenen Konservierungsstandards und einer mangelnden Koordination zwischen Ländern und Genbanken. Daraus ergaben sich neue Herausforderungen für das ECPGR, ein regionales Netzwerk für pflanzengenetische Ressourcen, das in den frühen 1980er Jahren gegründet wurde, um den Austausch von Protoplasma und Informationen zwischen den europäischen Ländern zu ermöglichen. ECPGR setzt einen starken Schwerpunkt in der Erhaltung genetischer Ressourcen von landwirtschaftlichen Nutzpflanzen, im Informationsmanagement und im Capacity Building. In den frühen 2000er Jahren wurde eine virtuelle europäische Genbank (AEGIS) gegründet, die unikate und wichtige Akzessionen aller in Europa eingelagerten pflanzengenetischen Ressourcen für Ernährung und Landwirtschaft enthält. AEGIS operiert im juristischen Rahmen des Internationalen Plant Treaty (ITPGRFA) und der Biodiversitätskonvention und widmet der Qualität von Erhaltungsstrategien gebührende Aufmerksamkeit. Der Beitrag liefert eine kurze Beschreibung der wichtigsten Managementaspekte der AEGIS. Am Ende finden sich einige kontroverse und philosophische Überlegungen.

1. Introduction

Political and development scenarios in Europe over the last 70 years have impacted on the decision to strengthen the collaboration between European countries for the conservation and use of plant genetic resources (PGR). Some of the main reasons for a strengthened regional collaboration are: countries in Europe have operated largely independent in the past with respect to PGR collecting and conservation; the focus and priorities of plant breeding were largely 'country driven'; no legal framework existed until the early 1990ies (i. e. Convention on Biodiversity, CBD); and no clear and agreed technical standards for conservation existed until recently.

The absence of adequate coordination had resulted in a very fragmented conservation scenario across Europe; in significant duplication of germplasm material between collections and countries (see also Graner, in this book); in very diverse quality standards across countries; in hardly any strategic research collaboration, e. g. to facilitate the use of germplasm; and, more recently, a reluctance to share germplasm owing to potential economic interest or due to uncertainties about the correct legal procedures to follow, in line with the convention on Biodiversity and/or the FAO International Treaty. Additional aspects influencing the European PGR context were the anticipated increasing role of regional institutions in the management of Plant Genetic Resources for Food and Agriculture (PGRFA), e. g. as foreseen by the current Global Plan of Action and the International Treaty on PGRFA ("Plant Treaty"), the economic pressures to become more efficient and effective, and the technological developments (in particular on information management and molecular biology).

In the early 1980ies, coinciding with the increasing worldwide alarm for the loss of genetic diversity of, in particular, traditional varieties and landraces of food crops,[1] including in Europe, a regional network (ECPGR)[2] was created with formal paying members. It operates under the oversight of its Steering Committee that is made up by National Coordinators and representatives of the major stakeholder institutions in Europe. The predominant focus through-

1 See Fowler, Cary and Pat Mooney, *Shattering. Food, Politics, and the Loss of Genetic Diversity*, Tucson/AZ 1990.

2 ECPGR website, *A safety network for our crops*, http://www.ecpgr.cgiar.org/, read on 21.12.2017.

out its existence has been on collecting, conservation, characterization and evaluation as well as information management of crops of relevance to Europe. With respect to information management, a European documentation system, consisting of an accession-level germplasm passport data catalogue (i. e. EURISCO) and more recently also including characterization and evaluation (C&E) data, has been established to facilitate the collaboration among genebanks and countries. Capacity building, joint research and more recently the sharing of responsibilities among the members of ECPGR have been added.

As a result of the declared willingness to share responsibilities during the early 2000s, an initiative was taken by ECPGR to establish "A European Genebank Integrated System" (AEGIS), with the following objective: "Conserve in a collaborative way and at agreed quality standards, the genetically unique and important accessions for Europe of all crops and making them available for breeding and research". It was decided to operate AEGIS entirely within the political framework of the International Treaty and thus, to see AEGIS as a direct contribution of countries to the implementation of the International Treaty. The so-called European Collection, the most important output of AEGIS, was conceptualized, tools and procedures developed and agreements with countries and institutions concluded that are willing to assume specified responsibilities. Since the early 2010s, the Collection is operational, functions as a *virtual genebank* and consists of designated accessions that are unique and important for Europe, formally placed in the public domain and under governmental control, for which countries explicitly assume long-term conservation responsibility and that are made readily available for purposes of research, breeding and training for food and agriculture.[3]

For the selection of European Accessions, ECPGR developed detailed requirements/criteria and procedures, to facilitate countries to identify the unique accessions from their collections. By focusing as a first step on material collected or bred in a given country it is assumed that this approach followed by all European countries will most likely result in predominantly unique accessions. Selected and designated accessions to be included in the European Collection have to be flagged in EURISCO. European Accessions are con-

3 E. g. the European Core Collection of garlic at the German IPK (see Graner, in this book).

served in accordance with technical standards agreed upon at the ECPGR level by the Crop Working Groups and in agreement with the principles of the AEGIS quality management system (AQUAS). For important aspects such as safety duplication (i. e. the formal duplication of accessions for safety reasons in another genebank, preferably in a different country and continent), distribution procedures as well as for record keeping, monitoring and reporting, detailed guidelines or policies have also been developed and agreed. It should be noted that ECPGR made arrangements with the *Svalbard Global Seed Vault* (SGSV) to use the Seed Vault deposit as one possible option that countries may choose to satisfy the AEGIS safety duplication requirements.[4] For the time being, AEGIS is focusing on germplasm material conserved ex situ in genebanks, either as seed in cold storage, as plants in field genebanks and/or as tissue or embryos in *in vitro* collections, or cryopreserved in liquid nitrogen. Recently, a concept for the *in situ* conservation of crop wild relatives in genetic reserves in Europe has been developed. Genetic diversity is also maintained on farm, with an increasing attention to facilitate adaptation to the changing climate, and diversification of crops and agricultural systems (see Frese, in this book).

In the last part of this chapter some more philosophical issues will be presented, including the dynamics of the European Collection and its accessions; the impact on the longevity of stored germplasm by different conservation methods, and the questions: how 'artificial' are these conservation methods?; how important is it to maintain the 'original' genetic make-up of an accession or is an accession allowed to change/adapt?; how important is it to achieve complementarity between *in situ* and *ex situ* conservation for the same diversity cap-

4 The *Svalbard Global Seed Vault* (SGSV) provides an additional security back-up for the world's crop diversity by accepting adequately treated and packaged seed samples that are already stored as safety duplicates at another genebank for their non-monitored storage in the permafrost. The Seed Vault aims at safeguarding the world's most important plant genetic resources for food and agriculture with a maximum level of security. The Seed Vault offers free-of-charge back-up for the seed collections held in genebanks around the world. Svalbard represents a remote and secure yet accessible location. The safety of the seed samples is ensured by the thick sandstone rock surrounding them and their long-term survival is ensured by the permafrost conditions that maintain the airtight seed samples well below freezing even in the unlikely event that the mechanical cooling (-18 °C) should fail. The SGSV is operated by NordGen under an agreement with the Norwegian Ministry of Food and Agriculture and the Global Crop Diversity Trust.

tured in accessions?; how can such complementarity be achieved?; do other complementary conservation approaches exist?; is there a fundamental 'conflict' between conservation and use?

2. *The importance of Europe as a region of crop diversity*

Europe is one of the important regions of diversity worldwide, in particular the Mediterranean sub-region. In a recent study 36 crops have been reported to have originated in the European region (Table 1) and another 28 crops share their European origin with two or more regions of diversity.[5] The importance of Europe as a centre of crop diversity is also demonstrated (at least to some extent) by a significant number of landraces and wild species, predominantly crop wild relatives that have been collected and are being conserved in European genebanks. A total of 252.000 accessions of traditional cultivars and landraces are reported in EURISCO, the European catalogue of plant genetic resources. In addition, a total of 139.000 accessions (or 7.5 % of total reported accessions) of wild species have been reported there.

The development of crop diversity in Europe has been facilitated by early and strong links with important centres of diversity/origin of agriculture, in particular with the Fertile Crescent where many important crops have evolved. These links have existed for thousands of years and were strengthened through the ancient cultures of the Egyptians, Greeks and Romans, all bordering the Mediterranean Sea. Furthermore, links with Central Asia and China have enabled the exchange of plant diversity and the expeditions of Alexander the Great to Central Asia and India during the period from 334–323 BC should be mentioned. Furthermore, since the arrival of the first people in Europe some 45.000 years ago, migration has been a recurrent phenomenon[6] and certainly contributed to the formation of plant and crop diversity as mentioned above. Also since the establishment in the modern era of the first overseas colonies

5 Khoury, Colin K.; Achicanoy, Harold A.; Bjorkman, Anne D. et al., "Origins of food crops connect countries worldwide", in: *Proceedings of the Royal Society B*, 283(1832)/2016, pp. 1-9.

6 Fu, Qiaomei; Posth, Cosimo; Hajdinjak, Mateja et al., "The genetic history of Ice Age Europe", in: *Nature*, 534(7606)/2016, pp. 200-205.

Anise, badian, fennel & coriander	Linseed
Apples	Lupins
Artichokes	Mustard seed
Asparagus	Oats
Cabbages	Olives
Carob	Pears
Carrots & turnips	Peas
Cherries	Peppermint
Chestnut	Plums
Chicory roots	Poppy
Clover	Rape & mustard
Currants	Rapeseed
Figs	Raspberries
Gooseberries	Safflower seed
Hazelnuts	Sugar
Hops	Sugar beet
Leeks	Vetches
Lettuce	Walnuts

Table 1. List of crops that have originated in the European region (from Khoury et al. 2016).

by European countries, a significant movement of (crop) plants has taken place and a number of crops were introduced from other continents.

An example of the significance of introductions to Europe is demonstrated by the list of 57 Post-Columbian crops that were brought to Europe from America.[7] Besides the introduction of new crops into Europe also the creation of new varieties through professional plant breeding that started in Europe as early as the second half of the 19th century, has been an important factor of generating genetic diversity. Such breeding efforts were frequently strengthened through targeted collecting missions in centres of diversity with the aim of adding new diversity to the working/breeding collections.

The above mentioned events, situations and other factors resulted in the impressive amount of crop genetic diversity and resources that can still be found in Europe and these certainly had their impact on the subsequent conservation efforts.

7 Crosby, Alfred W., *The Columbian Exchange: Biological and Cultural Consequences of 1492*, Westport/CT 1972.

3. Overview of the conservation efforts in Europe and worldwide

Worldwide, the value of plant genetic resources in sustaining food security and thus peoples' livelihoods has been recognized since the early 1900s. Especially plant breeding is largely depending on genetic resources for its success, a recognition that was further supported by the discovery of the inheritance laws by Gregor Mendel (1822–1884) a few decennia before and re-discovered in 1900. From this period onwards some of the first collecting expeditions were carried out worldwide by Nikolaj I. Vavilov (1887–1943) and Harry V. Harlan (the father of Jack R. Harlan, 1917–1998) to find, conserve and use plant genetic resources for research purposes and breeding programmes. N. I. Vavilov and his colleagues at the *All-Union Institute for Plant Industry* in Leningrad, later renamed and called VIR after Vavilov, continued to organize collecting expeditions during the 1920s and 1930s in the USSR and in over 50 countries in Asia, the Americas, Northern Africa and Europe. At the time of the outbreak of World War II, VIR maintained a national network of at least 40 satellite collections and breeding stations. The VIR seed collection in the 1930s contained the impressive number of about 250.000 samples from over 50 countries.[8] After WW II, the COMECON network, possibly the first PGR network in Europe, formed a foundation for the national collections of Hungary, Bulgaria, Poland, Czechoslovakia and the German Democratic Republic ("East Germany").

Already in the 1930s, it had become evident that traditional crop varieties and adapted landraces (until then the 'corner stones' of any agricultural production system) were being increasingly replaced by new improved varieties, in particular of the major staple crops, and the first alarm bells were sounded.[9] Systematic germplasm conservation activities outside the Soviet Union were first initiated by the UK and the German Reich around 1940[10] and followed later by other West European countries. However, it took until 1970[11] for

8 Plucknett, Donald L.; Smith, Nigel J. H.; Williams, John T. et al., *Gene Banks and the World's Food*, Princeton/NJ 1987, chapter 3.

9 Harlan, Harry V. and M. L. Martini: "Problems and results in barley breeding", in: *Yearbook of Agriculture*, Washington/DC 1936, pp. 303-346.

10 Stubbe, Hans, *Geschichte des Instituts für Kulturpflanzenforschung Gatersleben der Deutschen Akademie der Wissenschaften zu Berlin 1943–1968*, Berlin 1982.

11 Karafyllis, Nicole C. and Uwe Lammers, "Big Data in kleinen Dosen. Die westdeutsche Genbank für Kulturpflanzen ‚Braunschweig Genetic Resources Coll-

establishing the genebanks of Braunschweig (Federal Republic of Germany) and Bari (Italy), to name two of the biggest in Western Europe; Greece, the Netherlands and the Scandinavian countries followed in the 1980s.

Recognizing the importance of plant genetic resources (PGR) for food security in the world, in the 1970s *ex situ* collections were promoted by international institutions, in particular by the *Food and Agriculture Organization of the United Nations* (FAO) and the International Board for Plant Genetic Resources (IBPGR), later the International Plant Genetic Resources Institute (IPGRI), and now *Bioversity International*. During this period, international crop genebanks were established at research centres of the Consultative Group on Agricultural Research (CGIAR). Today there are approximately 1.750 genebanks or germplasm collections worldwide, of which an estimated 625 exist in Europe. Globally these genebanks house some 7.4 million accessions and approximately 2.0 million in Europe.[12]

The *Second State of the World Report* on plant genetic resources prepared by FAO in 2009[13] revealed that many of the existing collections are (still) in an unsatisfactory condition. Reporting countries and international collections mentioned a number of reasons, including excessive expansion of the collections; insufficient financial and human resources to manage these collections adequately; and backlogs of regeneration needs. Strengthened and harmonized documentation, characterization and evaluation; better linkages between *in situ* and *ex situ* conservation strategies; greater efforts to promote the use of conserved genetic resources and the mobilization of additional resources for conservation were reported as priority actions to improve the current situation. The report also showed that of the approximately 7.4 million accessions maintained in the world's genebanks, a significant proportion are unwanted duplicates,

ection' (1970–2006) und ihre Biofakte", in: *Technikgeschichte*, 84(2)/2017, pp. 163-200.

12 FAO, *Genebank Standards for Plant Genetic Resources for Food and Agriculture*, rev. ed. Rome 2014; Engels, Johannes M. M. and Lorenzo Maggioni, "AEGIS: a regionally based approach to PGR conservation", in: Maxted, Nigel; Dulloo, Mohammad E.; Ford-Lloyd, Brian V. et al. (eds.), *Agrobiodiversity Conservation: Securing the Diversity of Crop Wild Relatives and Landraces*, Wallingford 2012, pp. 321-326.

13 FAO, *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture*, Rome 2010.

while the level of formal safety duplication is still low.[14] These accessions are held mainly in seed storage facilities suitable for medium- to long-term storage and the Second State of the World Report also showed that countries in Europe held a large proportion of the collections for long-term storage. For more details on the concept of safety duplication see the section on AEGIS below.

The conservation of Europe's plant genetic resources continues to be fragmented, largely because it is still based on individual national programmes. Calls for an integrated approach to plant conservation efforts have repeatedly been launched in Europe over the last 35 years.[15] Considering that genetic diversity for most crop species crosses national borders and that conservation and effective use in plant breeding programmes is facilitated when the entire genepool is considered, the aim for a closer collaboration has always seemed to be a logical goal shared and acknowledged by national programmes.

4. Need for collaboration between European countries

Whereas some European countries belonged to the very first ones worldwide to start targeted genebank operations (e. g. Russia and Germany, as mentioned above), many others only started system-

14 Ibid.

15 Gass, Thomas and Frank Begemann, "International efforts to sustain ex situ collections: options for a closer cooperation in Europe", in: Gass, Thomas; Frese, Lothar; Begemann, Frank et al. (eds.), *Implementation of the Global Plan of Action in Europe – Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. Proceedings of the European Symposium, 30 June-3 July 1998, Braunschweig, Germany*, Rome 1999, pp. 109-115; Hardon, Jaap, "Plant genetic resources conservation in Europe: a retrospective", in: Gass, Thomas; Frese, Lothar; Begemann, Frank et al. (eds.), *Implementation of the Global Plan of Action in Europe – Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. Proceedings of the European Symposium, 30 June-3 July 1998, Braunschweig, Germany*, Rome 1999, pp. 3-7; Frison, Emile; Mitteau, Martine; Sharrock, Suzanne et al., "Sharing responsibilities", in: Engels, Johannes M. M and Lambert Vissers (eds.), *A guide to effective management of germplasm collections*. (*IPGRI Handbooks for Genebanks* No. 6), Rome 2003, pp. 107-121; Bothmer, Roland von, "The National Programme of Plant Genetic Resources – development and priorities in Sweden", in: *European Workshop on National Plant Genetic Resources Programmes. Report of an international workshop, 24-26 April 2003, Alnarp, Sweden (IPGRI)*, Rome 2006, pp. 8-11.

atic conservation efforts during the second half of the last century, all with their own objectives, scope and methodology. This, in the absence of coordination in the past, resulted into a very fragmented conservation and use scenario across European countries. Furthermore, this situation had also led to a significant duplication of germplasm material between collections and countries as well as to very diverse quality standards across countries.[16] More recently, a reluctance to share germplasm has been noted, possibly owing to the potential economic interest of individual countries and/or due to uncertainties about the increasingly more complex legal requirements.

The political and development scenarios in Europe, in particular over the last seventy years or so, have had a significant influence on the preparedness to join hands in trying to conserve the genetic wealth. Especially the Cold War and the split of Europe into two non-compatible camps did not allow east-west collaboration in the formal sense. The economic cooperation in Europe that eventually resulted in the European Union, did (and still does) not include and recognize the conservation of agro-biodiversity as a regionally coordinated effort; it was rather left to the individual sovereign states to take responsibility.

Since the early 1980ies when conservation and use of genetic resources became gradually a global issue (the establishment of the International Undertaking by the FAO member states in 1983 is an indication of that) the first collaboration efforts in Europe were made through collaborative projects (partly funded by the UNDP). The justifications and reasons for a closer collaboration among more than 40 countries in Europe over the years about researching, conserving and facilitating the use of PGRFA are manifold and include the following aspects:

(1) As most of the countries had operated in the past largely independent with respect to plant genetic resources (PGR) collecting and conservation, this had resulted in a huge duplication of efforts and resources across countries and ECPGR aims at reducing this.
(2) Many of the European countries are rather small, and most of the crop genepools that had originated within the European region are widely spread across countries. Thus, only a close collaboration can result in effective and efficient conservation.

16 Karafyllis and Lammers, *Big Data*.

(3) No legal framework for access and benefit-sharing existed until the early 1990ies when the *Convention on Biodiversity* (CBD) was concluded, later (in 2004) followed by the *International Treaty* (ITPGRFA) entering into force (see annex, in this book). Although now largely resolved, a number of legal issues still exist.
(4) No clear and agreed technical standards for the conservation and (facilitation of) use existed until recently (possibly as a result of the first 3 points) and in particular within the context of AEGIS this shortcoming is being addressed.
(5) The focus and priorities of plant breeding were largely country driven and are still predominantly conducted within the national context, thus resulting in a relatively sub-optimal use of the available diversity.
(6) Over the past years a growing trust among the European countries with regard to PGRFA could be observed, and it is fair to conclude that ECPGR has greatly contributed to this.
(7) An additional aspect that might have influenced the collaboration in Europe is the expected increasing role of regional institutions and networks in the management of PGRFA as for instance foreseen by the First and Second Global Plan of Actions as well as in the International Treaty on PGRFA.
(8) The economic pressure on countries to become more efficient and effective in general and certainly in publicly funded activities, as well as the technological developments, in particular on information management and molecular biology, is yet another aspect that facilitates regional collaboration.

5. Establishment and operation of ECPGR

As mentioned at the beginning of this chapter, the *European Cooperative Programme for Plant Genetic Resources* (ECPGR) was created as a collaborative programme among most European countries with the aim of ensuring the long-term conservation and facilitating the increased utilization of plant genetic resources in Europe. ECPGR operates through Working Groups, dealing with groups of crops (18) or with general themes related to plant genetic resources (3). These Working Groups are the actual coordinating platforms for technical activities of the ECPGR programme for each given phase of five years. A lean Secretariat is facilitating the work of the programme, currently hosted by Bioversity International in Rome, Italy.

The predominant focus throughout ECPGR's existence has been on collecting, conservation, characterization and evaluation as well as capacity building and information management of crop genetic resources of relevance to Europe. With respect to the latter, a European documentation system consisting of an accession-level germplasm passport catalogue (i. e. EURISCO), has been created and operated. Recently, EURISCO also includes characterization and evaluation (C&E) data, thus caring for all relevant information on genetic resources accessions conserved in Europe with the aim of facilitating the collaboration among genebanks and countries, providing easy access to the information and contributing to the implementation of the International Treaty and enabling the operation of AEGIS (see below). Capacity building, joint research and more recently the sharing of responsibilities among the members of ECPGR are important activities of the ECPGR Programme.

6. Legal Framework: CBD and "Plant Treaty"

The *Convention on Biological Diversity* (CBD) was concluded in 1992 and entered into force in 1993. It was negotiated largely by representatives of ministries of environment and has a strong focus on the (in situ) conservation of wild species in natural environments. Agricultural aspects were only added at the last moment and strengthened through Resolution 3 of the Nairobi Final Act of the Conference for the Adoption of the Agreed Text of the Convention on Biological Diversity.[17] In this Resolution, FAO was given the responsibility to seek solutions for some outstanding issues concerning plant genetic resources within the Global System for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Sustainable Agriculture, in particular, (a) access to *ex situ* collections not acquired in accordance with this Convention; and (b) the question of farmers' rights.

17 CBD, *Handbook of the Convention on Biological Diversity. Section IX Nairobi Final Act of the Conference for the adoption of the agreed text of the Convention on Biological Diversity*, [3]2005. Online at https://www.cbd.int/doc/handbook/cbd-hb-09-en.pdf, read on 21.12.2017.

The CBD is a framework agreement between states on the conservation, sustainable use and exchange of biological diversity (at the ecosystem, species and within-species levels) and its activities are squarely placed in the context of sustainable development and translating the principles of Agenda 21 into reality. Since the conclusion of the CBD several specific agreements have been reached, including the *Cartagena Protocol on Biosafety* (which aims to ensure the safe handling, transport and use of living modified organisms (LMOs) resulting from modern biotechnology that may have adverse effects on biological diversity, taking also into account risks to human health), the *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the CBD* (which aims at sharing the benefits arising from the utilization of genetic resources in a fair and equitable way) and a number of Thematic Programmes and Cross-Cutting Issues. The Thematic Programmes include Agricultural Biodiversity, Dry and Sub-humid Lands Biodiversity, Forest Biodiversity, Inland Waters Biodiversity, Island Biodiversity, Marine and Coastal Biodiversity and Mountain Biodiversity. Each programme establishes a vision for, and basic principles to guide future work and provide very useful ideas and tools for their implementation. They also set out key issues for consideration, identify potential outputs, and suggest a timetable and means for achieving these.[18]

The *International Treaty on Plant Genetic Resources for Food and Agriculture* (the Treaty) was adopted in November 2001 and entered into force in June 2004. The conservation and sustainable use of plant genetic resources for food and agriculture are key to ensuring that the world will produce enough food to feed its growing population in the future. In 1983, the Commission on Genetic Resources For Food and Agriculture was established,[19] and the voluntary International Undertaking on Plant Genetic Resources[20] was adopted. Another major step was taken in 1996 with the adoption

18 CBD website, *Thematic Programmes and Cross-cutting Issues*, https://www.cbd.int/programmes/, read on 21.12.2017.

19 FAO website, *Commission on Genetic Resources for Food and Agriculture*, http://www.fao.org/nr/cgrfa/cgrfa-home/en/, read on 21.12.2017.

20 FAO website, *International Undertaking*, http://www.fao.org/nr/cgrfa/cgrfa-about/cgrfa-history/en/, read on 21.12.2017.

of the *Global Plan of Action* at the Leipzig International Technical Conference on Plant Genetic Resources.[21]

The Treaty aims at recognizing the enormous contribution that farmers have made to the diversity of crops that feed the world; to establish a global system to provide farmers, plant breeders and scientists with access to plant genetic materials; and to ensure that recipients share benefits they derive from the use of these genetic materials with the countries where they have been originated. To achieve these aims a number of provisions have been generated, including:

- MLS on facilitated access and benefit-sharing rules covers 35 of the most important food crops (including most of their wild relatives) and 29 grassland and fodder species, through their inclusion in Annex I. The genetic resources included in the MLS are formally placed in the public domain, are under governmental control and management and are freely available to potential users in the Treaty's ratifying nations for some uses.
- Access and benefit sharing: The Treaty facilitates access to the genetic materials of the 64 crops included in Annex I that have been made part of the Multilateral System for research, breeding and training for food and agriculture. Those who access the materials must be from the Treaty's ratifying nations and they must agree to use the materials exclusively for research, breeding and training for food and agriculture. The Treaty prevents the recipients of genetic resources from claiming intellectual property rights over those resources in the form in which they received them, and ensures that access to genetic resources already protected by international property rights is consistent with international and national laws. To access material as described above a so-called Standard Material Transfer Agreement (SMTA) will have to be concluded between the provider and the recipient of the germplasm. In the SMTA the recipient agrees to share any benefits from their use through four benefit-sharing mechanisms established by the Treaty as well as some specific conditions for making such germplasm available to other users.

21 FAO website, *Global Plan of Action*, http://www.fao.org/agriculture/crops/core-themes/theme/seeds-pgr/gpa/en/, read on 21.12.2017.

– Farmers' rights: The Treaty recognizes the enormous contribution farmers have made to the ongoing development of the world's wealth of plant genetic resources. It calls for protecting the traditional knowledge of these farmers, increasing their participation in national decision-making processes and ensuring that they share in the benefits from the use of these resources.
– Sustainable use: Most of the world's food comes from four main crops – rice, wheat, maize and potatoes. However, local crops, not among the main four, are a major food source for hundreds of millions of people and have potential to provide nutrition to countless others. The Treaty helps maximize the use and breeding of all crops and promotes development and maintenance of diverse farming systems.

7. The establishment and operation of AEGIS

As a result of the declared willingness of countries to share (more) responsibilities with respect to the conservation of PGR, during the early 2000s an initiative was taken by ECPGR to establish *A European Genebank Integrated System* (AEGIS), with the following goal: "Conserve in a collaborative way and at agreed quality standards, the genetically unique and important accessions for Europe of all crops and making them available for breeding and research."[22] As per the Memorandum of Understanding (MoU) that has been concluded with each of the AEGIS member countries the following are the agreed objectives:

(I) To develop a more efficient regional system of conservation and sustainable use of PGRFA through the setting up of a European Collection.
(II) To promote and undertake other collaborative action for the rational conservation, management and sustainable use of PGRFA.

22 ECPGR, *A Strategic Framework for the Implementation of a European Genebank Integrated System (AEGIS). A Policy Guide. European Cooperative Programme for Plant Genetic Resources (ECPGR)*, Rome 2009.

(III) To facilitate the exchange of PGRFA in accordance with standard terms and conditions of exchange.
(IV) To promote the exchange of information regarding PGRFA among the Parties, other stakeholders and the broader conservation community; and
(V) To provide a mechanism for regional cooperation in the implementation of the International Treaty in the European region.

It was decided (i. e. objective 5) to operate AEGIS entirely within the political framework of the International Treaty and thus, to see AEGIS as a direct contribution of countries to the implementation of the International Treaty. The so-called European Collection (i. e. objective 1) is the most important output of AEGIS and was conceptualized as a virtual genebank of which the so-called Associate Member genebanks form the foundation. Specific tools and procedures have been developed and agreed upon with all the countries through the Steering Committee. As already mentioned above, a MoU has been concluded with each AEGIS member country. Furthermore, so-called Associate Agreements have been concluded between the respective National Coordinator and genebanks or genetic resources collections in that country to establish a formal basis for the collaboration.[23] Details on AEGIS can be obtained from its official website.[24]

Since the early 2010s the European Collection is operational, functions as a virtual genebank and consists of designated accessions that respond to the following obligatory requirements:

(1) Material under the management and control of the member countries and their Associate Members, in the public domain and offered by the Associate members for inclusion into AEGIS.
(2) Genetically unique within AEGIS, to the best available knowledge (i. e. genetically distinct accessions, assessment based on available data and/or on the recorded history of the accession).
(3) Plant genetic resources for food and agriculture as defined in the International Treaty, as well as medicinal and ornamental species.

23 Engels and Maggioni, *PGR conservation*.
24 ECPGR website, http://www.ecpgr.cgiar.org/aegis/aegis-homepage/, read on 21.12.2017.

(4) European origin or introduced germplasm that is of actual or potential importance to Europe (for breeding, research, education or for historical and cultural reasons).

The European Accessions are conserved for the long-term by the AEGIS member countries and its Associate Members, as per the aforementioned Associate Membership agreement, and are being made readily available under the same terms and conditions defined by the International Treaty to any user for purposes of research, breeding and training for food and agriculture.

For the operation of the European Collection a number of tools and instruments have been developed and endorsed by the Steering Committee. They form part of the AEGIS Quality System (AQUAS) and include:

(I) Generic and crop specific standards for the management of the respective crop genepool collections. The agreed FAO technical genebank standards had been accepted as the basis and most of the Crop Working Groups have developed additional crop specific standards.[25] Whereas the FAO standards agreed upon in 2014[26] have been widely accepted by the Crop Working Groups, some Groups added more species specific standards in order to manage the virtual collection of that crops/species more effectively.

(II) A safety duplication policy.[27] As this is an important routine conservation activity, but with very different degrees of implementation, it was decided to provide a detailed policy to the Associate Members on the actual distribution of European Accession material to users worldwide. Each accession should ideally have at least one clearly identified safety-duplicate that could be used as a back-up in case the original went lost. A formal arrangement is necessary to identify the back-up sample and to have the respective conservation and distribution responsibilities clearly assigned. On the other hand, duplicates created outside of a formal safety arrangement are unneces-

25 ECPGR website, *Genebank standards*, http://www.ecpgr.cgiar.org/aegis/aquas-quality-management-system-for-aegis/genebank-standards/, read on 21.12.2017.

26 FAO, *Standards*.

27 ECPGR website, *Policies – Safety duplication*, http://www.ecpgr.cgiar.org/aegis/aquas-quality-management-system-for-aegis/policies/, read on 21.12.2017.

sary from the point of view of a collection (such as the European Collection) that is meant to efficiently share resources and responsibilities among all the European countries.

(III) Guidelines for the distribution of germplasm material from the European Collection.[28] As for the conservation approaches at large, also the actual distribution policy of material included in the European Collection needed to be standardized in order to ensure a unified and harmonized approach between all the Associate Members.[29] Some examples of these Guidelines are that all germplasm samples for research, breeding and training will be provided under a Standard Material Transfer Agreement (SMTA), that the information about any request will be treated confidentially and that the providers of germplasm material will only attend to large requests if these are adequately justified.

(IV) The Steering Committee endorsed a document on 'Record keeping, reporting and monitoring of the European Collection'.[30] This document is an important element of the quality control aspect. It has been intended to make especially the reporting requirements as 'light' as possible. Furthermore, it should be noted that ECPGR is weary to have a 'policing' approach. Instead, capacity building has been seen as the more effective and successful way forward.

(V) The Secretariat also created a template for the development of an operational genebank manual by the Associate Members.[31] Such manuals will allow the recipients of the germplasm (and others) to learn in detail how a given Associate Member genebank has managed its accessions and thus to provide the foundation for AQUAS.

28 Engels, Johannes M. M. and Lorenzo Maggioni, *AEGIS Guidelines for Distribution of Material from the European Collection*, Rome 2013.

29 ECPGR website, *AEGIS Guidelines*, http://www.ecpgr.cgiar.org/fileadmin/templates/ecpgr.org/upload/AEGIS/FOR_WEB_FINAL/AEGIS_Guidelines_for_Distribution_of_Material_from_the_European_Collection_30.12.2013_COrrected.pdf, read on 21.12.2017.

30 Engels, Johannes M. M. and Lorenzo Maggioni, *Record keeping, reporting and monitoring of the European Collection*, Rome 2016.

31 ECPGR website, *Template*, http://www.ecpgr.cgiar.org/aegis/aquas-quality-management-system-for-aegis/template/, read on 21.12.2017.

In view of the fragmented situation with respect to conservation and use of PGR in Europe and the resulting unwanted duplication of accessions in two or more genebanks and countries, ECPGR had originally formulated selection requirements and criteria to select the unique accessions from the collective pool of conserved germplasm by the AEGIS member countries. The requirements of the selected accessions are listed at the beginning of this section. Furthermore, in order to guide the selection of the 'best accession' among the group of duplicates (in some cases crop specific) criteria were formulated. Initially, the selection responsibility was given to the Crop Working Groups as it was assumed that they would have the technical expertise to make the best possible decisions when selecting European Accessions from the respective crop genepools and known accessions maintained by the countries. As this process turned out to be rather complex it was agreed by the Steering Committee to request the member countries as a first step to identify from their holdings the accessions which had been originated in the country, either collected or bred.

By focusing (as a first step) on material collected or bred in a given country it is assumed that this approach, if followed by all European countries, will most likely result in predominantly unique accessions and thus will lead to only limited debate among countries and Working Groups. Individual selected and designated (i. e. formally accepted by National Coordinator) accessions to be included in the European Collection have to be flagged in EURISCO. European Accessions are conserved in accordance with above-mentioned technical standards agreed upon and in agreement with the principles of AQUAS.

8. Current status of AEGIS/European Collection

At present, AEGIS is still clearly focussing on ex situ conservation of germplasm material in genebanks, either as seed in cold storage (approximately 97.3 % of the accessions included in the European Collection), as plants in field genebanks (1 %) and/or as tissue or embryos in in vitro collections (1 %), or cryopreserved in liquid nitrogen (0.7 %). The total number of accessions formally included in the European Collection (on 3.11.2016) was 28.899. Details on which countries have included accessions in the European Collection can be found in Table 2.

Albania	8
Bulgaria	261
Croatia	90
Czech Republic	1.222
Estonia	15
Germany	7.904
Latvia	21
Netherlands	5.853
Nordic Countries	3.708
Poland	301
Romania	196
Slovakia	299
Switzerland	4.838
United Kingdom	4.183
TOTAL	28.899

Table 2. Number of accessions included in the European Collection by country (status per 21.7.2016).

It is noteworthy that the growth of the European Collection is rather slow, as only 1.5 % of the accessions documented in EURISCO have been included into the European Collection in July 2016, after AEGIS entered into force in July 2009. From interactions with National Coordinators and scientists from a number of countries, some sort of reluctance was felt to include identified accessions into the European Collection. Some of the presumed reasons that have led to this reluctance include: fear to assume responsibilities with financial cost implications; complex decision-making procedures; appearance of conflicting (real or perceived) interests among different national stakeholders (i. e. environment vs. agricultural ministries); and lack of national coordination mechanisms.

In order to move the 'designation' process of accessions to the European Collection forward, a paper on the "Benefits of establishing and operating a European Collection of unique and important germplasm" had been prepared[32] and discussed with the Steering

32 Engels, Johannes M. M. and Lorenzo Maggioni, *Benefits of establishing and operating a European Collection of unique and important germplasm*, Rome 2015.

Committee.

Recently, a concept for the *in situ* conservation of crop wild relatives in genetic reserves in Europe has been developed[33] and concrete suggestions were made to identify Most Appropriate Wild Populations and designate them for active *in situ* conservation, mirroring the process used in AEGIS for accession recognition at the European scale. This type of development will become more realistic whenever the European countries will collectively agree to facilitate access of *in situ* wild populations to users according to appropriate mechanisms and under the same standard terms defined by the International Treaty.

9. *Some challenges and an outlook towards future developments*

9.1 The dynamics of the European Collection and its accessions

That the European Collection develops rather slowly has a direct impact on the anticipated benefits of the Collection, as many of these benefits are dependent on an adequate representation of the total genetic diversity for a given crop genepool in the virtual Collection. This critical point has not yet been reached for any of the crop genepools. At present only a few countries have decisively moved forward by starting to place accessions that are under control and management of their respective government of many of the crop genepools (and certainly of most of the major crops) into the European Collection whereas many other countries are still in the process of making their selections.

As the inclusion of germplasm accessions into the European Collection is a rather 'formal' process (as countries and genebanks formally accept the responsibility to provide access and long-term conservation) it can be expected that it will take several years before such process will be concluded, unless increased priority is given to the process at country or regional level. As already mentioned and has been experienced by some of the Crop Working Groups, the second stage of selecting unique and important accessions (i. e.

33 Maxted, Nigel; Avagyan, Alvina; Frese, Lothar et al., *ECPGR Concept for* in situ *conservation of crop wild relatives in Europe. Wild Species Conservation in Genetic Reserves Working Group*, Rome 2015.

selecting accessions among duplicates) is more complex and time-consuming.

Another aspect of the dynamics of the European Collection is the possibility for countries to 'deflag' accessions (and thus to remove them) from the Collection, in case a mistake has been made or for whatever other reason. The only 'condition' for deflagging is that the reason(s) is/are mentioned in EURISCO. Examples for such reasons could be that the accession in question has no more viable seeds, or has been identified as a duplicate or funding for its maintenance is no longer available and therefore the accession should be "adopted" by a different institution. It is hoped that thus the European Collection remains rather flexible and dynamic and more attractive for countries to join and include material.

9.2 Germplasm conservation, methods used and longevity

As noted above, germplasm can be stored in a number of different ways. The most common and possibly the best known and researched method is the storage of so-called orthodox seeds (they can be dried to a recommended seed moisture content (smc) between 3 and 7 % water content, depending on the species) and stored under low temperature (for long-term conservation a temperature of -18 degrees Celsius is recommended; *method a*). The optimum smc of orthodox seeds varies with the species and would allow seed storage for several decennia, especially when stored at lower temperatures. The advantage of seed storage is certainly that bigger numbers can be stored at relatively low cost and thus, also genetically non-uniform accessions (as most of the landraces and crop wild relative populations) can be maintained without compromising the genetic integrity of such accessions (see next section).

Long-term conservation will be more difficult if no seeds are available for storage, i. e. in case of sterile species; or if they are recalcitrant (i. e. they 'resist' long-term storage as they cannot be dried to lower smc and consequently cannot be stored for long, if at all, at low or even ambient temperatures). Also crops that are vegetatively propagated (fruit trees, potatoes, pineapples, etc.) cannot be maintained as seed, since successful parental genotypes would be lost in the recombinant progeny (see Flachowsky and Höfer, in this book). In these cases, the accessions need to be maintained as living plants in a field genebank (*method b*) or as tissue/embryos/cell suspensions either at cool temperature (as so-called slow-growth *in vitro* collection; *method c*) or stored in liquid nitrogen (i. e. cryopreserved; *method d*); or ideally implementing more than one of the above methods for safety precautions.

Of the above mentioned methods, a) and d) have the potential of maintaining the longevity of seed and tissue/embryo/etc. for a long period, up to 100 years and more depending on the species (but with regular viability monitoring recommended in order to remain on the safe side!). Plants maintained in a field genebank (trees or other perennials) can survive for the lifetime of the given individuals, despite the continued exposure to the 'environment', including pests and diseases, when properly managed.

It should be noted that the stored germplasm might have to be regenerated when viability decreases or the stocks are depleted and this operation might affect the genetic integrity, if not properly done.

Besides seeds, tissues, embryos, cell suspensions and living plants, also pollen might be used for storage (a number of species produce long- and well-storable pollen; however, it only represents the male part of the genome and one also needs a female plant and an embryo to obtain the next generation). More recently also DNA is being stored (in this case no plants can be regenerated; the DNA can only be used as part of a molecular genetics programme or as a deposit of genetic information). All these *ex situ* conservation methods depend to a varying degree on permanent management, thus have a variable cost and potential vulnerability.

On the other hand, accessions maintained in farmers' fields (especially relevant for landraces and traditional varieties, but also weedy materials as part of a production system) or in natural habitats (crop wild relatives; wild plants used for food) are exposed to the changing environment and thus can adapt to new conditions (both, natural as well as cultural). They are also susceptible to genetic erosion or even extinction, if the climatic or cultural conditions change drastically (and this was the main reason to establish genebanks in the first place!).

It is interesting to observe that the conservation methods, starting from nature conservation, *on farm* management and *ex situ* methods such as seed conservation, field genebank and *in vitro* collections, including the use of cryopreservation and ending with DNA storage are increasingly more complex, use more advanced technologies and are thus more dependent on human involvement. At the same time, also the related costs increase whereas the possibility for the conserved material to evolve decreases or even disappears!

9.3 Maintaining the genetic integrity and identity of accessions

One of the objectives of *ex situ* conservation is to maintain the genetic integrity (i. e. maintaining the 'original' genetic composition of a genetic resources sample/accession) and identity (the descriptive information about a sample/accession, including its precise origin, possible names, characterization data, photographic material, herbarium and reference sample, and possibly other aspects) of accessions as close as possible to that of the original samples. Not only the biological parameters of a given species dictate the efforts that will be required to achieve this, also the genetic make-up of an accession can cause difficulties to achieve this. *Ex situ* conservation intends to adequately represent the genetic diversity of a given population (in the case of crop wild relatives or landraces), a traditional or modern variety or whatever in the sample that is being collected in a farmer's field, in nature or wherever. The genetic composition of such a sample, that becomes an accession when added to the genebank collection, varies from a complete heterogeneous population of individuals (in the case of, for instance, out-crossing CWRs and landraces) to completely uniform material (in the case of inbreeding species or clones). The maintenance of this genetic composition during conservation, i. e. keeping its integrity intact, is being seen as the most important task of the responsible genebank.[34]

It should be noted that genebank curators have to make conscious decisions how best to proceed for instance in case of heterogeneous and/or mixed accessions that under *ex situ* conservation are expected to be conserved while maintaining the genetic integrity of the original sample and at the same time the use of such accession will be increased/facilitated if and when relevant information on its content can be provided. The latter might well mean that one has to split such a heterogeneous accession into its genetic components and to characterize/evaluate these components and treat

34 For details see for instance Engels, Johannes M. M. and Lambert Vissers (eds.), *A guide to effective management of germplasm collections*. (*IPGRI Handbooks for Genebanks* No. 6), Rome 2003.

them as sub-samples and/or separate accessions.[35] This very constraint might also apply to material maintained *in situ*/on-farm as populations or heterogeneous material such as landraces is difficult to access and to characterize/evaluate as a population or mixed landrace in its entirety.

The maintenance of the genetic identity of a given accession has largely to do with management practices by the genebank in question, i. e. basically to not make mistakes while handling the material or its related information. It is essential that every individual accession does not get contaminated by being crossed or mixed or confused with others and that 'checks' and procedures are built into the routine operations to monitor and verify the identity of each and every accession.

Routine conservation operations such as regeneration of accessions can place a heavy burden on genebanks to maintain the genetic integrity as this might require costly measures (e. g. genetic isolation of accessions from each other; need for special equipment and conditions such as insect pollinators; need to initially discover suitable germination and growing conditions of little studied wild material). In summary, specialized knowledge of the individual crops/species that are being maintained in a genebank is needed to obtain optimal results (and this is sometimes problematic).

In the case of *in situ* (natural habitat and on-farm) conservation the aim of maintaining the genetic integrity and identity of a given population or landrace might vary with the precise purpose of the conservation effort (see Frese, in this book). Most typically, the aim is to allow the conserved or managed material to evolve with the changing conditions of the environment and/or of the management practices, still without losing the intrinsic variation and the characterizing traits. Therefore, *in situ* conservation is usually dynamic, allowing the material to adapt to new situations, whereas *ex situ* conservation is rather static, i. e. no changes are expected in the conserved material.

35 Sackville Hamilton, Nigel R.; Engels, Johannes M. M.; van Hintum, Theo J. L. et al., *Accession management. Combining or splitting accessions as a tool to improve germplasm management efficiency*. (*IPGRI Technical Bulletin* No. 5), Rome 2002.

9.4 Complementarity between *in situ* and *ex situ* conservation approaches

Considering the different objectives of *in situ* and *ex situ* conservation with respect to the genetic integrity of accessions, and recognizing that both these conservation approaches have their strengths and weaknesses when looking at specific aspects such as accessibility, availability, identity, safety (and others)[36] of the conserved material, it becomes clear that in an ideal world one would want to combine the strengths and eliminate the weaknesses, to the extent possible. Thus, to achieve the best possible scenario one will have to combine the two conservation approaches to achieve the optimum, i. e. to have the two approaches to complement each other. However, there are numerous hurdles to jump and challenges to master as part of the conservation and use efforts, including administrative challenges. As an example, the Ministry of Environment is typically responsible for the implementation of the CBD, i. e. predominantly the *in situ* approaches, whereas in most countries the Ministry of Agriculture is responsible for the implementation of the International Treaty (ITPGRFA) and thus for the conservation of crop genetic resources, largely conserved *ex situ*. Thus, it would be critically important to bring institutions that deal with these different approaches into one and the same coordination set-up, for instance in the national programme for PGRFA. It would also require that those local stakeholders such as farmers, farmers' organizations, (local) breeders and researchers, local politicians, representatives of local conservation projects and others are adequately involved and represented in oversight and steering bodies.

Not only at the oversight-level is the involvement of local stakeholders important, also in the conservation activities themselves it is crucially important to engage them in order to achieve sustainable and effective conservation efforts. Ideally, such stakeholders should become, whenever possible, the beneficiaries of the conservation, and certainly not the ones that would experience disadvantages as a result of potential restrictions to their economic activities. It has been experienced that an adequate involvement of stakeholders in the planning and implementation of the conservation activity might be a pre-condition to achieve a sustainable and long-lasting approach. In fact, it can be stated that conservation efforts function

36 For more details, see Engels and Vissers, *Germplasm collections*.

better if and when a broad participation and support for the operations can be obtained. This is true not only at the local (community) level, but also at the provincial, national, regional and global level! Complementarity of conservation methods can also be important within *ex situ* conservation by combining for instance accessions maintained in a field genebank with *in vitro* conservation, in particular cryopreservation as that would allow a long-term approach. In addition, by using tissue culture as an intermediate step this procedure could be used to also eliminate especially viruses from the tissue material. One could also think of using pollen as a complementary approach to field genebank or *in vitro* conservation, just by increasing the options and spreading and even reducing the risk of losing material. More details on complementary or integrated conservation can be found in Engelmann and Engels (2002).[37]

9.5 Potential 'conflict' between conservation and use?

AEGIS has a clear focus on effective and efficient conservation, but its primary aim is to facilitate the use of the conserved genetic resources. Usefulness of conserved accessions is enhanced through their characterization and evaluation, by making this information more readily available to users (through EURISCO) and by seeking and adopting germplasm management practices that make the use of the material easier and more targeted. There is no conflict between conservation and use. The two objectives can be achieved through good genebank management and, moreover, conservation without use would be hardly justifiable. An example of a situation where the genebank curator has to make 'difficult decisions' to combine long-term conservation with facilitating use is the storage of cryopreserved tissue and the need for alternative storage approaches as it might take too long to obtain flowering plants from cryopreserved tissue. In such cases it seems to be justified to manage a field genebank in parallel to the cryopreservation. In general, it should be noted that different concepts with respect to conservation have evolved and can be experienced during political discussions in meet-

37 Engelmann, Florent and Johannes M. M. Engels, "Technologies and strategies for ex situ conservation", in: Engels, Johannes M. M.; Rao, V. Ramanatha and Anthony H. D. Brown (eds.), *Managing Plant Genetic Diversity*, Wallingford 2002, pp. 89-103.

ings of for instance the CBD and the International Treaty. Some of the recurrent issues are the apparent conflict between agriculture and conservation of biodiversity, the ownership over genetic resources and related information, and the use of (debated) molecular technologies to breed new varieties.

10. Some conclusions and outlook

It has been widely recognized that the continued loss of (agricultural) biodiversity can only be stopped or reduced through targeted, effective and efficient conservation efforts. This is indeed a critical recognition in order to ensure that we keep options open for future generations to decide what to grow and to eat. These options are dependent on the availability of genetic diversity, both at the crop as well as at the within-species level, to allow the development of adapted varieties for the cultivators during periods with drastic changes in the environment, among others caused by climate change.

As the distribution of genetic diversity of crops and other potentially useful species does not follow political borders, and considering the fact that in regions such as Europe countries are very diverse in size, economic strength, agricultural history and other aspects that might impact on the effective and efficient conservation, a well-coordinated effort at the regional level seems to be indispensable. Such collaboration also contributes to a more effective and powerful utilization of the conserved diversity.

As part of the regional collaboration, ECPGR had decided to take an initiative that would directly address rational, effective and efficient conservation and use. The initiative builds on the long-term commitment of countries to conserve unique and important germplasm material and to make this readily available to users. The development and operation of a quality management system, including agreed standards as well as reporting and monitoring responsibilities, is a crucial element of AEGIS. The European Collection is operational but still growing rather slowly. The related administrative burden on countries and the required long-term commitment seem to be the main reason for the slow growth.

Whereas the complementarity of *in situ* and *ex situ* conservation is a logical and important concept, and possibly indispensable to achieve an effective and efficient conservation, it should be realized that regional collaboration, certainly in Europe but possibly also elsewhere, is more advanced for the *ex situ* side. This is partly because *ex situ* approaches on a larger level were implemented earlier and that targeted research on genebank conservation practices started earlier than for *in situ* conservation (see Frese, in this book). It was only with the conclusion of the CBD that *in situ* conservation of crop genetic resources became more widely accepted and used. Furthermore, *in situ* conservation approaches are typically country-specific and often independently implemented at the local level. As a consequence, regional coordination is difficult and possibly not even that essential to achieve successful *in situ* conservation programmes. It is possibly the national legal and policy framework that will be important to facilitate local and community initiatives and that seems to be the area where ECPGR and collaboration can make its contributions through the development of model legislation and policies. Considering the above, in particular the constraints of *ex situ* conservation to conserve all genetic diversity in genebanks and thus, the indispensability of ensuring effective and efficient *in situ* conservation, the need to integrate conservation 'thinking' more widely into the daily life of the average people seems an important prerequisite. It is clear that this can only be achieved with the necessary political support.

There is a need to understand that regional (or wider) collaboration for conservation makes more sense than raising barriers across countries, in order to increase the efficiency as well as to widen the diversity of genetic material that everyone should be able to use. Furthermore, multilateral approaches seem to be better aligned with regional and international collaboration than nationalistic thinking. Ideally, a strong incentive to collaboration could be promoted by the European Union, should a EU Strategy on Genetic Resources for Food and Agriculture (EU Agrobiodiversity Strategy) be developed and implemented with an attached regional budget. On the other hand, the recent EU Regulation for the implementation of the Nagoya Protocol sets a few standards relating to users' compliance with international agreements on access to germplasm and sharing of the benefits, but it falls short of defining a common approach on the provision of access to the material. This opens the door to a continued fragmentation into different national approaches with the risk of increasing uncertainty and bureaucracy in providing/obtaining access with little benefit either for the community of stakeholders or for the interests of each individual country.