A Global Strategy for the Conservation and Use of Cacao Genetic Resources, as the Foundation for a Sustainable Cocoa Economy

Compiled by Brigitte Laliberté

CacaoNet
Global Network for Cacao Genetic Resources

Bioversity International

CacaoNet is the Global Network for Cacao Genetic Resources, coordinated by Bioversity International with member representatives from various cocoa research institutes and organizations that support cocoa research. CacaoNet aims to optimize the conservation and use of cacao genetic resources as the foundation of a sustainable cocoa economy (from farmers through research to consumers), by coordinating and strengthening the conservation and related research efforts of a worldwide network of public and private sector stakeholders. www.cacaonet.org

Bioversity International is a world leading research-for-development non-profit organization, working towards a world in which smallholder farming communities in developing countries are thriving and sustainable. Bioversity International's purpose is to investigate the use and conservation of agricultural biodiversity in order to achieve better nutrition, improve smallholders' livelihoods and enhance agricultural sustainability. Bioversity International works with a global range of partners to maximize impact, to develop capacity and to ensure that all stakeholders have an effective voice. www.bioversityinternational.org

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Disclaimer

This document has been developed by cacao genetic resources and breeding experts. The objective of this document is to provide a framework for the efficient and effective conservation of the globally important cacao genetic resources and strengthening their use. This strategy document is likely to continue evolving and being updated as and when information becomes available. The views and opinions expressed here are those of the contributors and do not necessarily reflect the views and opinions of their individual institutes. In case of specific questions and/or comments, please direct them to the CacaoNet Secretariat at Bioversity International.

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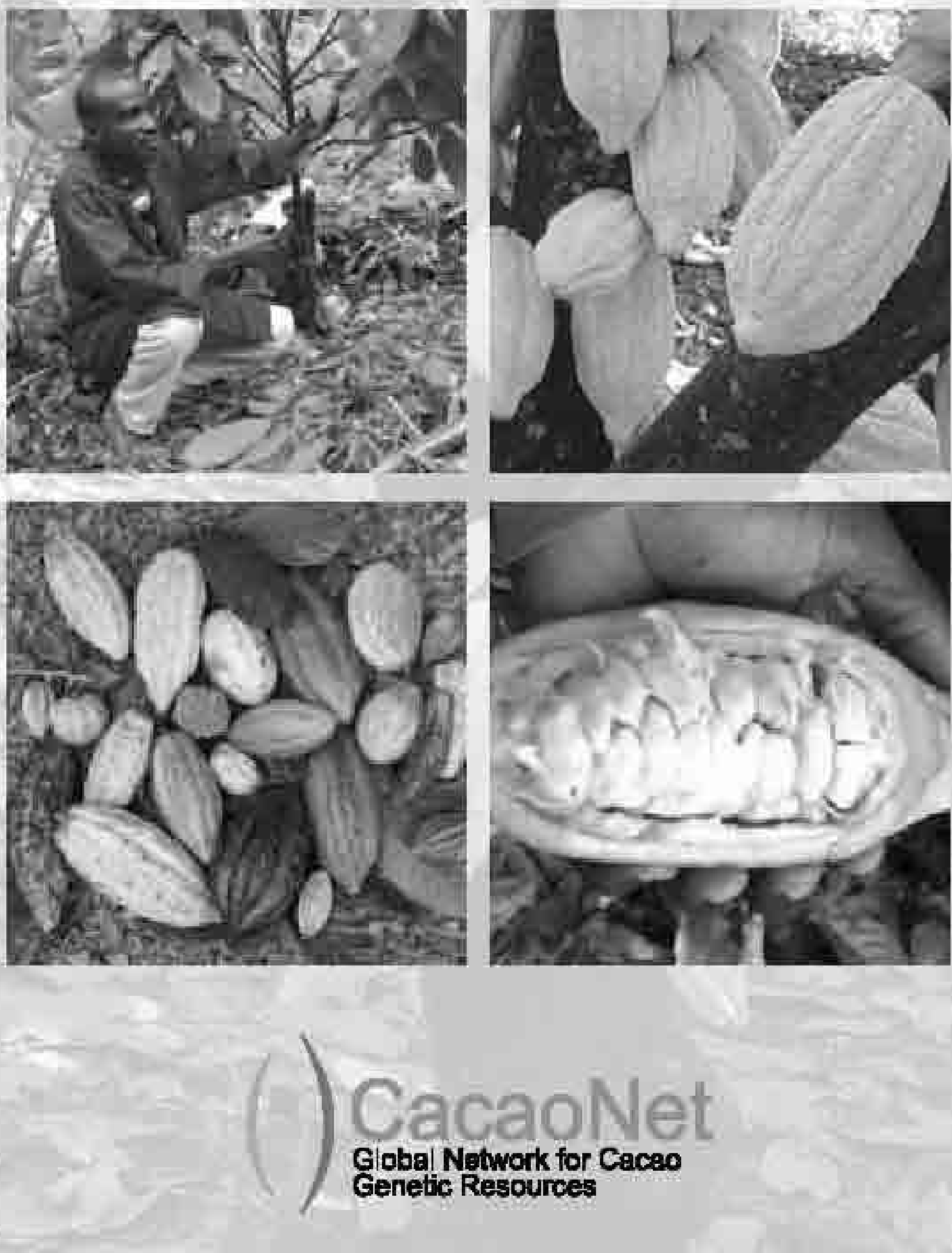

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This strategy document, coordinated by CacaoNet, is the product of expert opinion and detailed discussion among diverse stakeholders in the conservation and use of cacao genetic resources. CacaoNet considers that it has provided an informed and realistic foundation for prioritising cacao research and development. The goal is to use this strategy to invigorate the commercial cacao sector in a sustained manner, while protecting food security, by encouraging partnerships that increase impact of research and adoption of technological innovations. CacaoNet encourages international, regional and national public research organizations, development agencies, NGOs and the private sector to use the priorities set out herein to guide their activities and investment decisions.

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Preface

On behalf of all the donors that have generously supported the preparation of this important document, it is a pleasure to write this brief preface. The publication of this Global Strategy is the culmination of a major international effort, involving many experts, many revisions and intense discussions over a long period of time, amongst members of the cocoa research community who have often had strongly held views on the best way forward. We believe that, although time consuming, this international debate has been fruitful and will have greatly strengthened the Global Strategy that is presented here.

Some 95% of global cocoa production comes from small cocoa growers who might have an average of some three hectares allocated to the crop with perhaps an annual yield of some 330 kg per hectare leading to their producing about one tonne of dried beans per annum. The cultivation systems described later in this Global Strategy cannot be considered as sustainable and they barely, if at all, deliver a living wage to such a cocoa farming family. As a minimum, current cocoa farm productivity needs to be trebled. Cleary the availability of a broad range of genetic resources and breeding from them to provide improved planting material will have a major role in enhancing the sustainability of cocoa cultivation for the myriad of small growers who presently face a somewhat uncertain future.

In view of the substantial international importance of the trade in cocoa and the several millions of very small farmers in the tropics involved in its cultivation, some observers have expressed surprise that the crop was not designated as a priority crop in the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). In the absence of such an international legal and financial framework to support its conservation and use, cocoa is a vulnerable crop vis-a-vis its long-term and sustainable funding. However, thanks to the strong commitment and efforts of CATIE and CRU/UWI to ensure global access to these resources by designating their collections under the ITPGRFA Article 15, these valuable genetic resources can be accessed for utilization and conservation in research, breeding and training and the benefits arising out of their use shared in a fair and equitable way. This Global Strategy for the Conservation and Use of Cacao Genetic Resources has been developed since we believe that this will greatly enhance the impact of this work and the opportunities to get international support for the development of better cocoa planting material.

We gratefully acknowledge the contribution of the experts who so freely gave of their time and their opinions, as well as the vision of the sponsors that has enabled the completion of this important piece of work. The supporters of this strategy development process and the wider cocoa industry look forward to working with national authorities and international donors to effectively deliver the vision laid out in this Global Strategy.

Tony Lass, Chairman
Cocoa Research Association Ltd., UK (CRA Ltd)

Abstract

The future of the world cocoa economy depends on the availability of genetic diversity and the sustainable use of this broad genetic base to breed improved varieties. Decreasing cacao genetic diversity (*in situ*, on-farm and conserved in collections) is a serious problem and all its many causes need to be urgently addressed: the destruction of the Amazonian rainforests, changing patterns of land use, the spread of pests and diseases, sudden changes in climate, and threats from natural disasters and extreme weather. These factors are resulting in an irreversible loss of the cacao genetic diversity so essential for farmers, breeders, and consumers. Most of the countries involved in the improvement and production of cacao are highly dependent on genes and varieties characterized and conserved in other countries and regions. Effective management of cacao genetic resources can therefore only be carried out through international collaboration.

Most of the planting material is low yielding, often due to its high susceptibility to prevailing pests and diseases but also due to deteriorating soil and environmental conditions. However, preliminary evaluation of collections and farmers' populations shows a wide variation in disease resistance and cocoa quality. Furthermore, only a few varieties have been selected for sensory quality aiming at the specialty cocoa market. Compared to many other tree crops, there has been little investment in scientific research to improve cacao production, and the number of breeders is very low.

Cacao genetic diversity is an essential element in the development of new and improved varieties to achieve a more sustainable and cost-effective means of cocoa production, thus contributing to the economies of cacao producing countries. A considerable portion of this diversity is *in situ*, in farmers' fields and held in genebanks around the world, including two international collections maintained at the Cocoa Research Unit of the University of the West Indies (CRU/UWI), Trinidad and Tobago, and at the *Centro Agronómico Tropical de Investigación y Enseñanza* (CATIE), Costa Rica. Unfortunately, much of the genetic resources maintained in national collections is under-used or at risk, and funding remains insufficient and unstable. Utilization of these collections can contribute to cocoa production through delivery of improved varieties only through strong national breeding programmes. Such programmes are under-resourced in most countries and capacity building in this area is critically important.

The vision of the Global Strategy for the Conservation and Use of Cacao Genetic Resources is to improve the livelihoods of the 5-6 million farmers in developing countries across tropical Africa, Asia and Latin America who produce around 90% of cocoa worldwide, and the 40-50 million people who depend upon cocoa for their livelihoods.

The specific goal of the Global Strategy is to optimize the conservation and maximize the use of cacao genetic resources as the foundation of a sustainable cocoa economy. This it does by bringing together national and international players in public and private sectors.

The expected outputs are: (1) the cacao genepool is conserved *in situ* and *ex situ* for the long term by a global network of partners, (2) the global system for the safe exchange of cacao germplasm is strengthened, (3) the use of cacao genetic diversity is optimized and, (4) the effectiveness of global efforts to conserve and use cacao genetic resources is assured.

A cocoa farmer in Côte d'Ivoire (D. Pokou, CNRA).

To ensure these outputs are implemented, the first and urgent task will be to secure funding for the existing cacao genetic diversity currently maintained in *ex situ* collections and accessible in the public domain. CacaoNet will work towards the establishment of an endowment fund for the conservation and use of the most valuable resources in perpetuity.

At the centre of the Global Strategy is the Global Strategic Cacao Collection (GSCC): a "virtual genebank" of accessions of highest priority for conservation, wherever they are physically located. A first set of accessions will be selected to capture the greatest range of genetic (allelic) richness, reducing any bias that might be introduced by selecting phenotypic characters. It is acknowledged that some of that unique diversity may only be held in national collections currently unavailable beyond their national boundaries. However, inclusion of the materials in the GSCC will be on the basis that the governments concerned will be willing to place them in the public domain, and will take the necessary political and legal steps to do so. A further set of accessions, currently in the public domain, will be selected to capture key traits of interest to users. The formation of the GSCC will result from a coordinated effort of characterization, rationalization and safety duplication.

The Global Strategy, developed by the Global Network for Cacao Genetic Resources (CacaoNet), is the result of a consultation process that drew upon the global cocoa community's expertise in all aspects of cacao genetic resources. It provides a clear framework to secure funding for the most urgent needs to ensure that cacao diversity is conserved, used and provides direct benefits to the millions of small-scale cacao farmers around the world.

1. Introduction to the Global Cacao Strategy

1.1 Background

Although the term "cocoa" is generally used for the plant and its products in many English speaking countries, this document will refer to "cacao" for the plant and the unprocessed seeds of the species *Theobroma cacao*. Once the cacao seeds, commonly known as "beans", are harvested, fermented and dried, the product is known as cocoa. Beans are shelled and roasted, and then ground to form a paste known as "liquor". Some cocoa liquor is pressed to extract the fat, known as cocoa butter, leaving cocoa powder which is used in drinks and confectionary. Cocoa liquor and butter are usually combined with sugar, milk and other ingredients to form chocolate. In addition to its use as food, cocoa butter is also used in very small quantities in pharmaceuticals, soaps and cosmetics.

1.1.1 History and origins of the cocoa trade

Chocolate was drunk as a frothy and bitter drink by the Aztec elite. (Museo del Cacao, Granada, Nicaragua).

The genus *Theobroma* originated millions of years ago in South America, to the east of the Andes. *Theobroma* is divided into 22 species of which *Theobroma cacao* is the most widely known. It was the Maya who provided tangible evidence of cacao as a domesticated crop. Archaeological evidence in Costa Rica indicates that cacao was drunk by Maya traders as early as 400 BC. Dominant in Mesoamerica from the fourteenth century to the Conquest in the sixteenth century, the Aztec culture revered cacao. It was greatly appreciated by the Mayan and Aztec peoples for the preparation of a rich drink, and played an important role in their culture and commerce. The first outsider to drink chocolate is said to have been Christopher Columbus, who reached Nicaragua in 1502. But it was Hernan Cortés who returned to Spain in 1528 bearing the Aztec recipe for xocoatl (chocolate drink) with him (ICCO website, Growing cacao).

The type of cacao historically grown in MesoAmerica (from central Mexico down through Central America, including Guatemala, Belize, Honduras and El Salvador) and the circum-Caribbean region (including Mexico, Central America, and the Caribbean), is known to the cocoa trade as "Criollo" (meaning native) and is characterized as having lightly pigmented beans which have a delicate flavour and require little fermentation.

The exploitation of natural stands of cacao along river banks began and cacao was planted in new areas eastwards towards the mouth of the River Amazon. These Amazonian types of cacao were quite different from the Criollo types and came to be known as "Forastero" (meaning foreign – from another part of the country).

With the increasing popularity of chocolate, the rush by Europeans to claim land to cultivate cacao continued through the late seventeenth and the eighteenth centuries, and farms were established throughout the circum-Caribbean region, the Caribbean islands, Ecuador and new areas of Brazil, including Bahia, which later became the main area of cultivation.

One of the oldest populations cultivated for commercial purposes outside of the circum-Caribbean region is the "Nacional" type found in the coastal regions of Ecuador to the West of the Andes. The origins of this population are unknown, though may derive from the Upper Marañon river basins, and the type is still grown and known to the trade for its unique flavour characteristics. A recent collecting mission made in the Ecuadorian southern Amazonia region allowed the rescue of a few wild trees whose genetics are quite close to members of the "Nacional" population (F. Amores, pers. com 2012).

Where planting materials were exchanged between different areas, new hybrid populations developed, which often had better growth and disease resistance characteristics than the rather weak Criollos but also had distinctive flavour characteristics. The term "Trinitario", although perhaps only originally applied to such hybrid populations between Criollo and Forastero types, occurring in Trinidad, has since been used to describe types arising as products of hybridization and recombination through various generations, which are now known in the trade for their floral/fruity flavours. Pods, seeds and/or plants of the original Trinitario populations from Trinidad reached Ecuador (from Venezuela) in the late nineteenth century.

Another type resulting from the hybridization between the original Nacional populations and the introduced Trinitario from Venezuela is known as "Refractario". These were selections made from trees which had survived witches' broom disease (WBD) infection which caused heavy losses. Refractario types can be found in the genebanks in Trinidad and Tobago and Costa Rica representing an interesting source of genetic diversity.

From the mid-seventeenth century onwards, there were attempts to introduce cacao to other parts of the world, though only small numbers of plants would have survived, due to the long sea crossings involved (see Figure 1). Cacao of Criollo, Amelonado and Trinitario types was introduced from Mesoamerica, Trinidad and Venezuela to the Philippines, Indonesia and Ceylon, and from there to other parts of Asia and the Indian Ocean region (Van Hall, 1913; Bartley, 2005). Remnants of these populations can still be found, for example in the fine flavoured cocoas from Java traded today.

With the establishment of chocolate manufacturing in Europe in the second half of the eighteenth century and the increase in chocolate consumption in North America, there was an explosion in demand requiring yet more cacao to be cultivated. Cacao growing in West Africa spread rapidly following the introduction of a Lower Amazonian type, called "Amelonado", (due to its melon shaped pods), from Brazil to Principe in 1822, and from there to São Tomé in 1830, Fernando Pó in 1854, Ghana in 1861, Nigeria in 1874, and Côte d'Ivoire in 1919. In Cameroon, cacao growing was first recorded in 1876 with a shipment of 13 plants from the Royal Botanic Gardens believed to be from Trinidad to a British missionary (Bartley, 2005). Later on, and particularly during the colonial period, different types of cacao were introduced from South and Central America, such that the country now produces a distinctive type of cocoa. Despite a few more documented introductions, much of the cacao grown in the rest of West Africa has a rather narrow genetic base ("West African Amelonado"), though efforts to introduce a wider range of genetic diversity, especially from the Upper Amazon types, through breeding programmes are continuing. Figure 1 from Bartley (2005) shows the principal routes of the movement of cacao germplasm from 1660 onwards.

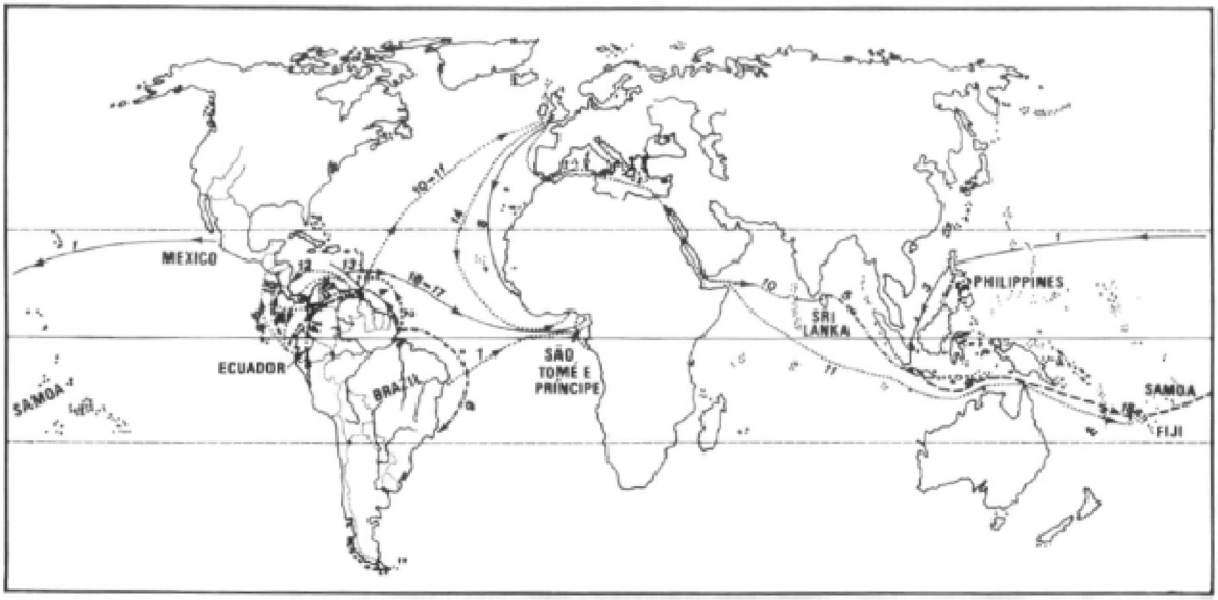

Fig. 35. Map of the world showing the principal routes of the movement of cacao germplasm within the American continent and islands and from the American continent to the Eastern Hemisphere. **1.** 1660–1670, Mexico to Philippines; **2.** 1664, Amazon to Martinique; **3.** Philippines to Indonesian Archipelago; **4.** 1757, Amazon to Trinidad; **5.** Early 19th century, Indonesian Archipelago to Ceylon; **6.** 18th and 19th centuries, Amazon to southeastern Brazil; **7.** 1822, Brazil to Príncipe; **8.** 1840s, Dublin to Sierra Leone; **9.** 1861, Ecuador to Guatemala; **10.** 1880/1881 Trinidad (via England) to Ceylon; **11.** 1883, Trinidad (via England) to Fiji; **12.** 1892/1893, Trinidad to Nicaragua, Nicaragua to Trinidad; **13.** 1898, Trinidad to Costa Rica and Colombia; **14.** 1890, Venezuela to Ecuador; **15.** 1930s Ecuador to Costa Rica and Panama; **16.** 1880s Trinidad, Venezuela and Ecuador to São Tomé; **17.** 1899, Trinidad, Venezuela, Ecuador and Central America to Cameroon; **18.** End of 19th century, Indonesian Archipelago to Samoa.

Figure 1. Map of the world showing the principal routes of the movement of cacao germplasm. (Source: Figure 35 in: Bartley, BGD. 2005. The genetic diversity of cacao and its utilization. CAB International, Wallingford, UK).

Today West Africa accounts for some 75% of the total production of the traditional West African Amelonado and mixed hybrid types, commonly known to the trade as Forastero or "bulk" cocoa (ICCO, 2010-2011 production figures). Forastero, which is also grown on a large scale in Indonesia and Brazil, is characterized by mid to dark purple beans which present a strong chocolate flavour when properly fermented and processed.

1.1.2 Cultivation and current production of cacao

The cacao tree is grown in the tropics, with most of the production in a band within 8° from the equator, sometimes called the "Cocoa Belt". Cacao requires hot, moist conditions to grow and will not withstand prolonged drought conditions without seriously depressing the tree´s vegetative and reproductive functions. In West Africa most farmers establish their cacao plantation from seeds. Some farmers have access to seeds resulting from bi-parental crosses (sometimes called "hybrid" crosses) carried out in seed gardens, and some farmers use seeds from their own or neighbours trees for new plantings. In Latin America and Asia clonal planting materials are widely used, which have been propagated by budding or grafting on to rootstocks, by cuttings, and in recent years also through somatic embryogenesis (tissue culture).

Trees take approximately three years to bear their first fruits, commonly known as "pods", and remain productive for several decades. High yielding clones however are very precocious and first harvesting of ripe pods occurs at two years after planting. The cacao flowers develop directly on the trunk and main branches of the tree (cauliflorous) and are pollinated by small insects. The pods take approximately five to six months to develop and once ripe consist of a thick husk enclosing some 25-50 seeds by a sweet pulp. Once harvested, the cacao pods are opened and the pulp and seeds are separated from the husks manually.

Cacao tree, Brazil
(A. Eskes, CIRAD/Bioversity).

Most cacao is fermented on farm. The cacao is generally fermented in simple heaps covered by banana leaves, resulting in variable cocoa bean quality, though fermentation in trays, wooden crates or baskets is practised in some areas. Fermentation generally takes three to six days depending on local practices and variety. The beans are commonly sun-dried, though artificial drying is used some areas where continuous rainfall does not allow drying in the open, to ideally reduce the moisture content to 7.5%. The fermentation process initiates the formation of flavour precursors which are only fully developed following drying and roasting.

Cocoa pod EET 103, Ecuador
(E. Cros, CIRAD).

Most cocoa is bagged directly after drying (on farm and/or sometimes by local traders) for transmission to the ports for export or local processors. Before making cocoa and chocolate the beans are roasted, usually by the manufacturer to develop the final chocolate flavour. Finally the shells are removed from the roasted beans, and the beans are ready for making chocolate paste, cocoa, cocoa butter and chocolate.

Fermentation in bags, Martinique
(Ph. Lachenaud, CIRAD).

Statistics from the International Cocoa Organization (ICCO) indicate that cocoa is produced mainly on small-scale farms in developing countries across Africa, Asia and Latin America. Around 90% of the world cocoa production comes from farms with only two to five hectares (ICCO, 25 July 2011). According to the World Cocoa Foundation (WCF), the number of cocoa farmers worldwide is 5-6 million and the number of people who depend upon cocoa for their livelihood, worldwide is 40-50 million (WCF website May 2012, Cocoa Facts & Figures). Producing approximately 75% of global output, West Africa is economically the most important cocoa producing region in the world. The most important countries in Africa are: Côte d'Ivoire (40% global), Ghana, Nigeria and Cameroon. In Asia and Oceania the countries are: Indonesia, Papua New Guinea, and Malaysia. In the Americas, the countries are: Ecuador, Brazil, and Colombia (WCF website May 2012). Some other countries and regions produce small amounts of cocoa but have an international reputation for producing fine flavour cocoa, such as the Caribbean Islands, including Cuba, Dominican Republic, Grenada Jamaica and Trinidad and Tobago, and countries in Central and South America such as Venezuela, along with a few others such as Java and Madagascar.

Millions of small farmers and landholders throughout the tropics depend on cacao for their livelihoods. The annual production worldwide of cocoa is estimated at 3990 million tonnes for 2011-2012 (ICCO, 2012). The monthly average of daily prices for cocoa beans for the period from January to June 2012 varied between 2264 US to 2359 US per tonne (ICCO, 2012), making the estimated global annual market value between 8-10 billion USD.

World production and demand have shown an erratic upward increase. The ICCO Secretariat estimates that demand will exceed supply with expected growth of cocoa consumption in Brazil, China, Eastern Europe, India and Russia. There is an average increase in demand of 3% per year (for the past 100 years). The industry estimates that it will require an extra million tonnes by 2020 (ICCO, 2012). Looking to the future, if this trend continues, demand is likely to be even doubled by the time the current breeding efforts are delivering in the field in 15-20 years.

1.1.3 Importance of cacao genetic diversity

Cacao genetic resources are an essential element in the development of new and improved varieties to achieve a more sustainable and cost-effective means of cocoa production, thus contributing to the economies of cacao producing countries (see Figure 2).

Cacao genetic resources comprise the range of genetic variability that provides the raw material for breeding new and improved varieties. They cover all material from uncultivated *Theobroma cacao* and related species growing in the forests of South and Central America, to the accessions held in national and international genebanks (both as *in vitro* and field genebank collections), to material in breeders' trials and trees growing in farmers' fields.

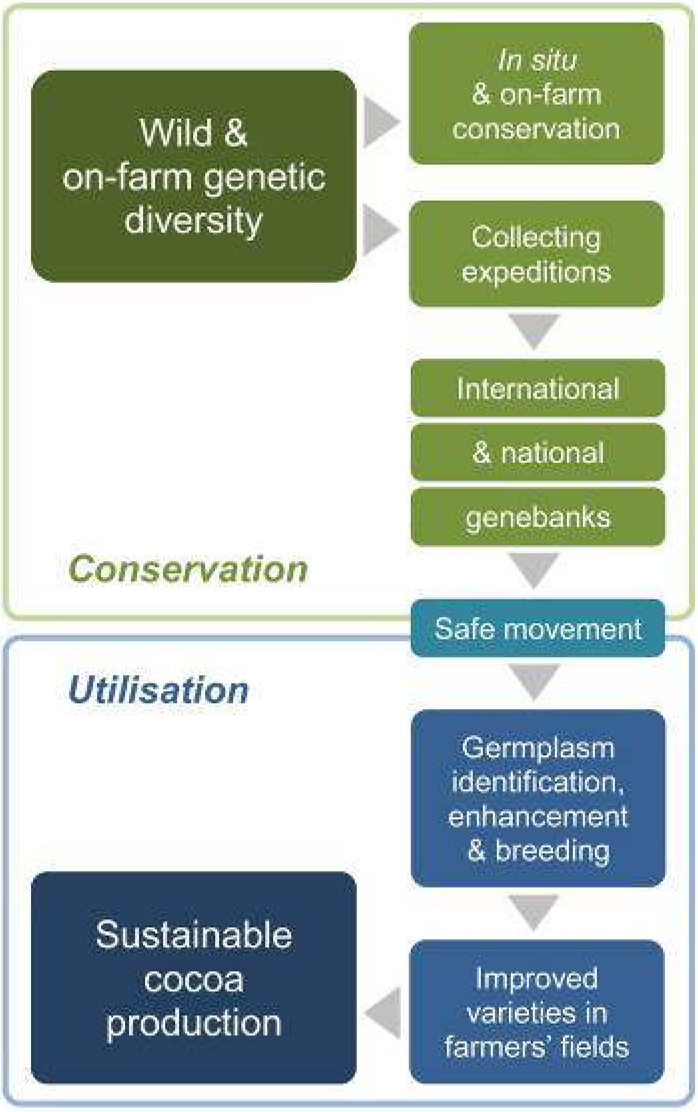

Figure 2. Links between the genetic diversity and sustainable cacao production (Credit: C. Turnbull, Reading University).

For many crop plants, germplasm can be stored in the form of dried seeds at low temperature (i.e. so-called 'orthodox' seed storage) but this is not possible with cacao, whose seeds are recalcitrant, i.e. they normally germinate as soon as they are removed from the pod and will not survive drying and/or storage at low temperature. Cacao germplasm can be conserved in two ways:

(1) *ex situ*, i.e. comprising all cacao germplasm currently maintained in field genebanks as living trees and/or in *in vitro* collections as tissues and embryos, or

(2) *in situ*, i.e. in farmers' fields for cultivated materials or in protected areas such as nature reserves for wild or semi-wild materials.

Effective conservation and management of cacao genetic resources includes the following routine activities: targeted collecting actions, maintenance of key field collections, effective characterization and identity studies, evaluation for important traits, information management, safe exchange of germplasm, and germplasm enhancement (in some cases).

Ex situ collections play a crucial role in the conservation of many varieties, particularly those that have already disappeared from farmers' fields. New germplasm can be introduced into a field genebank as seedling trees, for example from pods collected from the wild, but in most cases this material is subsequently vegetatively propagated by budding or grafting to produce genetically identical trees ("clones") for security, characterization and distribution purposes. *Ex situ* field genebank collections have the advantages that once the trees are established they can remain in the ground for many decades and can readily provide the budwood, seed or pollen needed for evaluation and incorporation into breeding programmes. However, such collections can be at risk from natural disasters such as fire, flooding and hurricanes and require maintenance to ensure weeds, pests and diseases are controlled. For many other crops, *in vitro* collections, i.e. as tissue/embryo culture on agar or another medium, have been used for safety duplication of the field collections and for rapid multiplication and dissemination of disease-free planting material. These technologies may have potential for cacao and should be investigated further.

Recent developments in cryopreservation technology, i.e. storing germplasm in the form of tissue, cell suspensions or as embryos, in liquid nitrogen at –196°C, may offer a complementary way to conserve cacao without the need for frequent sub-culturing. However, application of this technology also requires further investigation.

A considerable range of cacao genetic diversity is currently held in genebanks. There are an estimated 40 cacao genebanks around the world. Most are supported by national and/or public-private funding. There are currently only two international collections managed by the Cocoa Research Unit of the University of the West Indies (CRU/UWI), Trinidad and the Centro Agro-nómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica. These collections are known as the International Cocoa Genebank, Trinidad (ICG,T) and the Inter-national Cacao Collection at CATIE (IC3), respectively. These institutes concluded agreements with the International Treaty for Plant Genetic Resources for Food and Agriculture (ITPGRFA) to maintain their respective collections as global collections of cacao genetic resources for the long term and to make the germplasm freely available to any professionally qualified institution or individual.

Cacao diversity contained in CATIE´s *ex situ* collection Costa Rica (Allan Mata/ Wilbert Phillips, CATIE).

Although the international collections at CATIE and CRU/UWI have been supported by public and industry sources for many years, this support has not been secured for the long term. Their strong international commitment of putting the collections under the auspices of the ITPGRFA requires sustainable funding to ensure these resources are conserved and made available in perpetuity.

The safe movement of germplasm at the global level, including virus indexing, is achieved through the International Cocoa Quarantine Centre (ICQC,R), an intermediate quarantine facility supported by the chocolate industry and USDA, at the University of Reading, UK. The USDA/ARS facility in Miami, USA, offers quarantine facilities for regional transfers.

The benefits of conserving and utilizing the cacao genetic diversity will only be realized if this diversity is of interest and is made available to researchers engaged in breeding programmes. Scientists worldwide have been working for years towards producing cacao trees that can resist evolving pests and diseases, tolerate droughts and other environmental stresses and produce higher yields of good quality cocoa.

Their progress will be accelerated if they are provided with more information on the germplasm available, including its agronomic traits, disease/pest reaction, and flavour characteristics to help them prioritize materials for evaluation in breeding trials. Moreover, a better understanding of how to select for yield determinants and adaptation to planting density, together with selection against undue losses or damage from yield-limiting pests and diseases is urgently needed to improve the effectiveness of breeding programmes based on recurrent selection.

Emerging powerful new technologies such as molecular genetics, genomics, proteomics and eco-geographical remote-sensing techniques have greatly expanded the technologies supporting the conservation, management and utilization of genetic resources. Advances in informatics and communication technologies have also markedly increased our capacity to use, analyse and communicate related data and information.

In 2010, Mars Incorporated, the US Department of Agriculture-Agricultural Research Service (USDA/ARS), and IBM released the preliminary cacao genome sequence and made it available in the public domain (USDA/ARS, 2010). In a separate project, researchers from France's agricultural research centre CIRAD, from Pennsylvania State University, and from eighteen other institutions sequenced the genome of a *T. cacao* variety of the Criollo type from Belize, known to have a highly homozygous genome. With more and more information becoming available on the cacao genome, including the identification of genetic markers and candidate genes for commercially important traits, together with the rapid progress being made in understanding the interactions between the genome and the environment, it is anticipated that these techniques will complement and enhance traditional breeding approaches.

It is however acknowledged that the Global Strategy for the Conservation and Use of Cacao Genetic Resources (hereafter called 'the Global Strategy') will continue to require strong conventional cacao breeding programmes and better understanding of why it has proved so difficult to realize the full potential of cacao.

1.1.4 Major threats to cacao genetic resources

The threats to cacao genetic resources include pests and diseases, loss of genetic diversity, economic challenges and restricted access to the resources as well as habitat destruction and deforestation. Rehabilitation of old cacao farms has been progressing rapidly in the area of Upper Amazon, supported by the introduction and dissemination of high yielding and disease resistant clones in this region. The large-scale replacement of local varieties by introduced ones with reduced diversity is still on-going.

Infected pods, VARTC collection, Vanuatu (R. Markham).

A field grafted with a few clones with reduced genotype diversity can considerably reduce the allelic diversity within farmer fields. More importantly, most of the traditional varieties are being wiped out in this region. So far, economically viable methods of on-farm conservation are lacking, and little is known about the dynamics of diversity change in farmers' fields.

Despite the existence of over 24,370 cacao germplasm accessions in *ex situ* collections worldwide, including 3500 accessions that are held in the two international collections, much of this germplasm is underused, or indeed at risk, due to the lack of adequate long-term funding to ensure that it can be conserved and utilized effectively. Moreover, genetic studies suggest that the material held in *ex situ* genebanks, particularly the international genebanks, does not fully represent the known range of diversity and it is highly likely that yet more genetic variation remains to be discovered in the rainforests and farmers' field of the Amazonian region. It has been estimated that even in Brazilian Amazon, where the greatest collecting activity has taken place, only some 20% of the potential diversity has been explored (Bartley, 2005) and other areas, especially in Bolivia, Colombia, Ecuador, Peru and Venezuela, remain largely unexplored for cacao diversity. With the rapid deforestation in this region, drastic changes in land use and replacement of traditional cacao varieties with modern ones, both in the Amazon region and in other regions where cacao is grown, there is the likelihood of irreversible genetic erosion unless further steps are taken to conserve materials *in situ*, or to collect and conserve them *ex situ*.

Much of the germplasm in *ex situ* collections is poorly safety-duplicated outside of this host collection, mainly due to lack of funding. This puts the material at risk from loss, particularly due to pests, diseases or extreme weather events. It is important that steps are taken to ensure that representatives of the most genetically diverse types are systematically duplicated at a least one distant site, either as field collections or as a tissue cultured/cryopreserved sample to ensure that this material is not lost forever if the original tree dies.

Many of the cacao genetic resources are currently under-used, mainly because little information is available on the current and potential value of these resources. This situation has limited the linkages between genebanks and potential end-users. In cacao, as in many other crop plants, this problem is especially serious in the case of the *in situ* and on-farm conservation of traditional farmers' varieties, and increasingly of wild relatives, which are largely found in developing countries. The scarcity of economic resources in these countries is not only an obstacle to the protection of wild species, but also a major cause of genetic erosion, as people search for fuel-wood or convert virgin areas into farmland.

Access to cacao germplasm and information on key traits of interest to breeders is an essential condition for plant breeding research and agricultural development. National laws that restrict access of plant genetic resources have emerged in many countries. The introduction of intellectual property rights (IPRs) for new varieties and their genetic components in developed countries has been followed by application of national sovereignty and restrictions on access. Access conditions are constantly changing, especially for those species that do not fall under the terms and conditions of the ITPGRFA[1] and its multilateral system (MLS). The recently agreed Nagoya Protocol and access and benefit-sharing of biodiversity, as part of the Convention on Biological Diversity (CBD), will require further changes and adjustments. In addition, the lack of reliable information on cacao accessions held in genebanks hinders efficient management and significantly reduces their value to breeders, farmers and other users of the germplasm. The existing germplasm information systems need continued support to improve accessibility and interpretation of the information available.

1.1.5 The Global Cacao Genetic Resources Network - CacaoNet

The creation of a global network was proposed in 2005 to optimize the conservation and use of cacao genetic resources worldwide for the benefit of breeders, researchers and farmers. The Global Network on Cacao Genetic Resources Conservation and Use, CacaoNet, was officially launched at the COPAL 15th International Cocoa Research Conference in San José, Costa Rica, in October 2006, recognizing:

- the need for cacao breeders to have access to diverse germplasm and information about that germplasm in order to develop new varieties resistant to current and emerging threats from pests, diseases and other stresses,
- that breeders and producers also need access to such germplasm and information in order to supply the cocoa and chocolate industry with high-quality cocoas suitable for preparing the diversified and high-quality products demanded by consumers,
- that the genetic diversity of cacao and its wild relatives that represent the source of genes useful to cocoa production are under threat from habitat loss, market forces and other influences,
- that considerable resources are already being invested by the private and public sectors in the conservation, characterization and safe exchange of cacao genetic resources but that the cost-effectiveness of these efforts could be greatly enhanced through clearer policies and improved coordination.

CacaoNet's overall goal is to optimize the conservation and use of cacao genetic resources, as the foundation of a sustainable cocoa economy (from farmers through research to consumers), by coordinating and strengthening such conservation and related research efforts of a worldwide network of public and private sector stakeholders. CacaoNet brings together national and international players in both

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[1] The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA)- The objectives of which are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security. See: www.planttreaty.orgsecurity. See: www.planttreaty.org

public and private sectors and facilitate funding opportunities to be used for the support to conserving and utilizing cacao genetic resources.

One of the first internationally agreed priorities for CacaoNet was the development of a Global Strategy for the Conservation and Use of Cacao Genetic Resources. CacaoNet is uniquely placed to mobilize the cacao genetic resources community to come together and propose the components of a global collaborative strategy for strengthening the conservation and maximizing the use of these genetic resources in improvement programmes to ultimately benefit the many small farmers struggling with the vulnerability of a crop like cacao and the many devastating diseases that affects i*T. cacao*Net is currently funded by the Cocoa Research Association Ltd. (CRA Ltd.), Mars Inc., the United States Department of Agriculture (USDA) and the World Cocoa Foundation (WCF) and is coordinated by Bioversity International. For more information on CacaoNet see the website: www.cacaonet.org.

1.1.6 The need for a coordinated Global Strategy

At present, information exchange and coordination in the evaluation and improvement of cacao genetic resources relies largely on ad hoc groups such as the International Group for the Genetic Improvement of Cocoa (INGENIC) without stable funding and through informal contacts between scientists and research institutes.

The implementation of two major CFC/ICCO/Bioversity projects[2], initiated in 1998 demonstrated how multi-sector collaboration and shared priorities can help to set the agenda at a national and international level, aiming at more efficient use of cacao genetic resources to achieve common goals. However, the informal network created by the projects was limited in scope and in time. No support was provided for conservation and characterization of cacao genetic resources per se, and collaborative evaluation and selection activities came to an end upon completion of the projects in 2008.

Many other crop plants already benefit from a coordinated approach to the conservation of their germplasm supported by the Global Crop Diversity Trust (the Trust). This was established under international law in 2004, and was founded by FAO and Bioversity, acting on behalf of the CGIAR. The Trust is an endowment fund to safeguard *ex situ* collections of unique and valuable plant genetic resources for food and agriculture (PGRFA), with priority being given to those that are included in Annex I to the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) or referred to in its Article 15.1(b). Cacao is not one of the crops listed in the Annex 1 but is included in the Article 15.1(b) under which the two international collections held at CATIE and CRU/UWI fall. Therefore the Trust may offer a route to manage funds designated for cacao conservation. Funding decisions by the Trust are based on priorities identified and agreed by internationally

[2] Cocoa Germplasm Utilization and Conservation: a Global Approach (1998-2004) and Cocoa Productivity and Quality Improvement: a Participatory Approach (2004-2010).

recognised Networks of experts and key stakeholders, and clearly defined in global crop strategies. The Trust developed priorities and guiding principles for the allocation of funds[3] and a set of specific criteria to be met before a collection will be considered for long-term funding support, such as: (1) the genetic resources are judged to be important within the context of an agreed global conservation strategy, the collections have effective links to users and is willing to act in partnership with others to achieve a rational system for conserving plant genetic resources and making them available.

International frameworks such as both the Food and Agriculture Organization of the United Nations (FAO) and its Global Plan of Action (GPA) for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture and the ITPGRFA call for a more efficient and effective global conservation and use system. This should be based on better planning and more coordination and cooperation, to reduce costs and build conservation and management work on crop diversity on a more scientifically sound and financially sustainable foundation.

The FAO Second Report (2010) on the State of the World's PGRFA reminded the community of the main challenges of safeguarding and increasing the use of PGRFA and the priorities to be addressed. The priorities directly addressed by a Global Strategy on the conservation and use of cacao genetic resources are the following:

- Strengthen linkages between stakeholders involved in conservation, genetic improvement, and seed production and distribution, and particularly the linkages between genebank managers and plant breeders.
- Strengthen linkages between *ex situ* and *in situ* conservation.
- Rationalize genebank collections.
- Increase informative documentation, characterization and evaluation of the genebank material.
- Adopt cost-effective biotechnologies for plant breeding and characterization of plant diversity collections.
- Assist developing countries in implementing the policies, regulations and legislation on PGRFA.
- Improve coordination amongst funders to ensure long-term financial support for PGRFA activities.

Most nations and regions involved in the improvement and production of cacao are highly dependent on genes and varieties developed and conserved *in situ* and *ex situ* in other countries or regions. Most of the efforts needed to manage these resources can therefore only be carried out through international collaboration and the participation of all partners.

[3] See:http:/www.croptrust.org/documents/web/RoleofTrustSept08.pdf

The protection of areas for *in situ* conservation would benefit all producer countries, and there should therefore be international participation in efforts to safeguard them. Furthermore, most nations and regions involved in the improvement and production of cacao are highly dependent on genes and varieties developed and conserved in other countries or regions. Most of the efforts needed to manage these resources can therefore only be carried out through international collaboration. There is now an urgent need for an integrated Global Strategy for the conservation and use of cacao genetic diversity and the organization and diffusion of related information by the cacao community.

1.2 Global Strategy vision, goal, objectives and outputs

1.2.1 Vision and goal

The vision of the Global Strategy for the Conservation and Use of Cacao Genetic Resources is to improve the livelihoods of the 5-6 million farmers in developing countries across tropical Africa, Asia and Latin America who produce around 90% of cocoa worldwide, and the 40-50 million people who depend upon cocoa for their livelihoods.

The overall goal of the Global Strategy is to optimize the conservation and facilitate the use of cacao genetic resources, as the foundation of a sustainable cocoa economy (from farmers, through research, to consumers) by bringing together national and international players in both public and private sectors. The Global Strategy promotes the rationalization of conservation efforts at regional and global levels through encouraging partnerships and sharing facilities and tasks.

The Global Strategy is intended to be used as a roadmap towards building an efficient and effective global system that focuses on the needs of small-scale producers. The Global Strategy should be an important guiding document for donors, international and national research organizations and the private sector, that will facilitate the raising of support by identifying funding priorities that ensure the conservation, availability and use for improvement of cacao genetic diversity worldwide.

1.2.2 Objectives

The objectives of the Global Strategy are to:

- Provide a platform for the coordination and implementation of priority cacao genetic resources research, breeding and use of improved varieties.
- Assess the global cacao genetic diversity and identify critical gaps in existing *ex situ* collections and prioritize collecting missions.
- Ensure the cost-effective long-term conservation of cacao genetic resources and access particularly to poorly-known gene pools.
- Strengthen the on-farm conservation of landraces and the *in situ* conservation of wild species especially where the natural habitat is threatened.
- Strengthen the use of the cacao genetic resources by providing support to breeders and key users through improved characterization, evaluation and

support to population enhancement programmes as well as distribution of improved varieties.

- Improve the documentation on cacao germplasm and the sharing of key information of most value to users.
- Strengthen the distribution mechanism and safe movement of germplasm.
- Strengthen the networking and partnerships for global collaboration.

1.2.3 Outputs

The expected outputs of the Global Strategy are the following:

- **Output 1:** The cacao genepool is conserved *in situ* and *ex situ* for the long term by a global network of partners maintaining the most important diversity of cacao genetic resources.
- **Output 2:** The global system for the safe exchange of cacao germplasm is strengthened.
- **Output 3:** The use of cacao genetic diversity is optimized.
- **Output 4:** The effectiveness of global efforts to conserve and use cacao genetic resources is assured.

To ensure these outputs are implemented, the first and urgent task will be to secure funding for the existing cacao genetic diversity currently maintained in *ex situ* collections and accessible in the public domain. CacaoNet will work towards the establishment of an endowment fund for the conservation and use of the most valuable resources in perpetuity.

1.3 Strategy development process

This Global Strategy is the result of a long process of consultations involving genetic resource specialists and crop researchers. The Global Strategy will continue to evolve and be dynamic as users' needs evolve. Bridging diverse cultures, philosophies, socio-economic context, approaches to research, development and business, to achieve greater and more sustainable food and agricultural development in the light of increased impact of changing climates are goals that can only be fully achieved together.

In preparation for the establishment of CacaoNet in 2006, a survey was conducted amongst the broader cacao community to gather information on perceived priorities and ideas for the *modus operandi* for CacaoNet. Information on conservation and use from a cacao breeding perspective was also obtained from INGENIC which conducted a survey amongst its members.

The launch of CacaoNet took place during the 15th International Cocoa Research Conference in San Jose, Costa Rica in October 2006. In 2008 an Expert Consultation on the establishment and composition of the Global Strategic Cacao Collection was held at Reading, UK. At the 16th COPAL conference in Bali in 2009, a presentation on the state of the Global Strategy was presented. In July 2011, a consultation meeting was organized in Reading, UK, to review a first draft Global Strategy, involving collection curators, breeders and other experts (see Annex 1).

Below is a chronology of meetings and consultations that contributed to the Global Strategy:

- May 2005: Proposal presented at WCF Partnership meeting, Brussels, Belgium
- August 2005: Brainstorming workshop on the establishment of CacaoNet Montpellier, France
- October 2006: 15th International Cocoa Research Conference, San José, Costa Rica
- May 2007: WCF Partnership meeting, Amsterdam, The Netherlands
- December 2007: CacaoNet Steering Committee meeting, Slough, UK
- March 2008: Expert Consultation and CacaoNet Steering Committee meeting, Reading, UK
- March 2009: CacaoNet Steering Committee meeting, Port of Spain, Trinidad and Tobago
- November 2009: 16th International Cocoa Research Conference, Bali, Indonesia
- May 2011: WCF Partnership Meeting & Roundtable, San Francisco, USA
- July 2011: CacaoNet Consultation meeting on the Global Strategy, Reading, UK.

During the period from 2006-2012, a detailed survey was conducted with over 50 cacao germplasm collection holders worldwide to establish a better understanding of the current status of their collections and their future needs (see Annex 2). Replies were received from genetic diversity managers from 31 institutions (see Annex 3).

The Global Strategy was developed under the coordination of CacaoNet, with expert input from its members. The following steps were followed in the drafting, reviewing and finalization of the document:

1. Based on the proposed outline for the Global Strategy, identified cacao scientists were contacted to solicit technical documentation.
2. Existing drafts of specific sections and other documents available were consolidated and data analyzed from surveys.
3. Draft sections were reviewed by the key contributors.
4. A first draft for the Global Strategy was developed during the period January to June 2011.
5. A CacaoNet consultation meeting was held in Reading, UK in July 2011.
6. The second draft Strategy was reviewed by contributors and wider group of stakeholders.
7. The Strategy was finalized in July 2012.

It is expected that the continuous review and updating of this Global Strategy will take place within the framework of CacaoNet and this document will serve as the basis for the direction of the global system on the conservation and use of cacao genetic resources.

2. Where we are now on cacao germplasm conservation and use

2.1 The genetic diversity of cacao

2.1.1 The cacao genepool

Cacao (*Theobroma cacao* L.) is a neo-tropical tree species in the family *Malvaceae* (previously *Sterculiaceae*) (Reference: *Integrated Taxonomic Information System - ITIS, TSN 505487*) and is native to Tropical America. The primary gene pool of cacao is in the Amazon basin, ranging from French Guiana to Bolivia, where a large spectrum of wild populations still exists spontaneously. The different populations are morphologically variable, but there is no reproductive barrier between them.

Cocoa pods diversity (S. Weise, Bioversity).

The centre of diversity of cacao is in the upper Amazonian rainforest. In this region, a series of major river systems in Peru, Ecuador, Colombia, Venezuela and Brazil flow into the Marañón and the Amazon River. Among others, these include the rivers Chambira, Huallaga, Japura, Javari, Morona, Nanay, Napo, Negro, Nucuray, Pastaza, Purus, Putumayo, Santiago, Tigre, Ucayali, and Urituyacu. Recent molecular analyses suggest that the diversity of natural cacao populations might be stratified by the major river basins (Thomas et al., 2012). Within each river basin, wild cacao is grouped in patches and separated by large spatial distances between patches. Gene flow is limited and mating is likely confined within patches due to short-distance seed and pollen dispersal. Only a very small fraction of the diversity was dispersed from the Amazon to Mesoamerica and thus the ancient cultivated materials have a narrow genetic background. The crop genetic diversity for the most part resides within this region, in nature, as wild trees associated within forests, as relics from ancient cultivations or as trees within existing farmer fields.

2.1.2 Cacao taxonomy

There are 22 related species in the genus *Theobroma*, of which 15 are edible, and may have a great importance as gene reservoirs for cacao improvement (Table 1).

Table 1. *Theobroma* species and respective section, according to the classification proposed by Cuatrecasas (1964).

Sections and *Theobroma* species	Common name
Section *Andropetalum*	
T. mammosum Cuatr. & León	
Section *Glossopetalum*	
T. angustifolium Moçiño & Sessé	'cacao de mico'
T. canumanense Pires et Fróes	
T. chocoense Cuatr.	
T. cirmolinae Cuatr.	
T. grandiflorum (Willd. ex Spreng.) Schum.	'cupuassu'/ 'cupuaçu'/ ´Copoasu´/ ´Cupuasu´
T. hylaeum Cuatr.	
T. nemorale Cuatr.	
T. obovatum Klotzsch ex Bernoulli	' cabeça de urubu'/ ´Cacahuillo´/ ´Ushpa cacao´
T. simiarum Donn. Smith.	
T. sinuosum Pavón ex Hubber	
T. stipulatum Cuatr.	
T. subincanum Mart.	'cupuí'/´Macambillo´/´Macambo Sacha
Section *Oreanthes*	
T. bernouillii Pittier	
T. glaucum Karst.	
T. speciosum Willd.	'cacaui'
T. sylvestre Mart.	'cacau azul'
T. velutinum Benoist	
Section *Rhytidocarpus*	
Theobroma bicolor Humb. & Bonpl.	'mocambo'/ 'patashte'/ ´macambo´
Section *Telmatocarpus*	
T. gileri Cuatr.	
T. microcarpum Mart	'cacaurana'
Section *Theobroma*	
Theobroma cacao	'cacao'

These *Theobroma* species have a natural dispersion in tropical lowland rainforests extending from the Amazon basin through to southern Mexico (18° N to 15° S), but they all have an inter-specific crossing barrier with cacao, thus have not made an actual contribution to cacao improvement as yet (Figure 2).

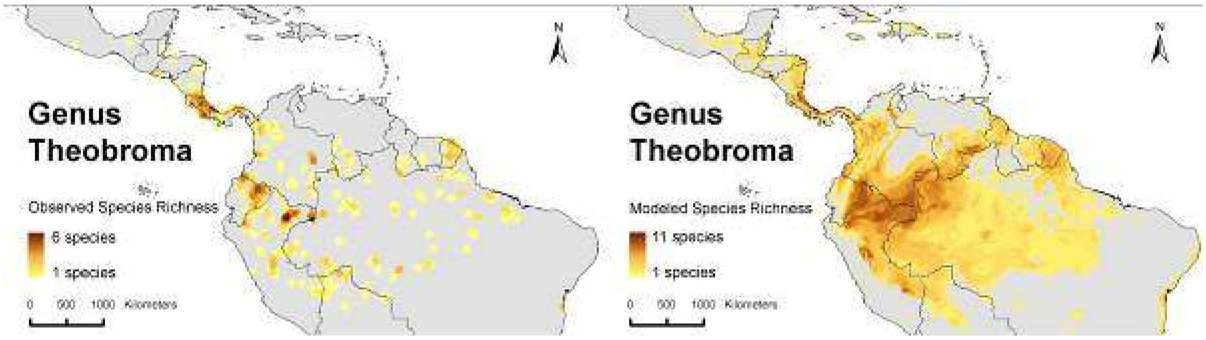


Figure 3. Species richness of genus *Theobroma.*

Left figure: observed species richness in 10 minute grid cells and a circular neighbourhood of 1 decimal degree; Right figure: modelled species richness in 2.5 minute grid cells (Source: Thomas et al., 2012).

All these related species produce fruits of potential commercial value, mainly because of the sweet seed-surrounding pulp, but only *T. grandiflorum* (cupuassu), *T. bicolor*, and *T. angustifolium* are cultivated. *T. grandiflorum* is considered an important fruit crop in various Amazonian countries and its cultivation has been increasing, especially in Brazil. Considerable work has been done on intergeneric and interspecific crosses involving these species and cacao with variable levels of success. The 'tertiary genepool' germplasm consists mainly of various species of the genus *Herrania*.

As new technologies are developed, these related species could become important sources of genes for cacao improvement. Hence, it is imperative that a systematic collecting of these species should be made and maintained in the collections for safe keeping.

2.1.3 Domestication of cacao

Cacao was domesticated at least 3000 years ago in Mesoamerica. The diverse uses of cacao led to it being widely grown in Mesoamerica before the arrival of the Europeans. The cultivation of cacao is believed to have spread more widely in South America in the early 18th century. However, since there is little difference between cultivated and wild cacao in terms of their agronomic traits, varieties directly adopted by farmers from spontaneous or semi-spontaneous populations were commonly found in various countries, such as Ecuador, Brazil, Peru and Bolivia. Starting from the 17th century, cacao was moved from its native region to other parts of the world including West Africa, South and South East Asia and to the Pacific, where they have been further hybridized to create varieties with local adaptation. Today, the cacao genotypes cultivated in the Americas consist of local varieties and hybrids derived from introduced germplasm, and the proportion of introduced germplasm varies country by country. In the region of Upper Amazon, the high level of indigenous intra-specific variation is often confounded with introduced germplasm or modern varieties.

There are different types of cultivated cacao with different attributes such as yield, disease resistance and sensory traits. As mentioned earlier, cultivated cacao has been traditionally subdivided into two main groups: Criollo and Forastero. A third group, Trinitario, has been recognised and is a hybrid between Criollo and Forastero. Two other traditional cultivars within Forastero, i.e. Nacional and Amelonado, have been described.

Criollo cacao was the originally domesticated form in Mesoamerica and is mainly grown in Central America and northern South America. It has white or pale violet beans that require very little fermentation to give a delicate chocolate flavour and are used in the production of specialty chocolate. However, Criollo is highly susceptible to pests and diseases, its yield is fairly low and very little Criollo cocoa enters the world trade. Criollo cocoa is often mixed with other varieties when making chocolate.

Forastero type cacaos were originally collected from natural and semi-natural stands growing alongside rivers in the Amazon. Exports increased from the mid-18th Century as cultivation spread eastwards, nearly as far as the mouth of the Amazon. Forastero cacao was brought to the traditional cocoa producing regions in Central America and the Caribbean when the cacao plantations were devastated by unknown causes. Forastero or bulk cocoa (as well as the hybrid type between Forastero and Trinitario) makes up over 95% of the world production and is cultivated mainly in Africa but also Central and South America. It grows faster and gives higher yield than other cacao types. Forastero produces highly pigmented beans, used in the manufacture of cocoa butter and high volume chocolate production.

Trinitario, cultivated mainly in Central and South America, Caribbean and Asia, is believed to be the natural hybrid of Criollo and Forastero. Trinitario derives its aroma from Criollo and some disease-resistance from Forastero.

2.2 Cacao genetic diversity conservation methods

For many crop plants, germplasm can be stored in the form of dried seeds and at low temperature (i.e. so-called ‘orthodox’ seed storage). But cacao seeds are recalcitrant, i.e. they normally germinate as soon as they are removed from the pod and cannot survive the drying process and/or storage at low temperature. Therefore, cacao germplasm has to be maintained as living trees in field genebanks, as tissue or embryos *in vitro* or *in situ* in farmers’ fields or as populations in protected areas such as nature reserves.

2.2.1 *Ex situ* conservation methods

Ex situ conservation of cacao germplasm (i.e. kept in specialized facilities known as genebanks) is carried out through field genebanks, *in vitro* collections and cryopreservation. *Ex situ* collections play a crucial role in the conservation of many varieties, particularly those that have already disappeared from farmers’ fields and are an essential link between genetic diversity in nature and its users. The main drawback of *ex situ* conservation is that only a relatively small amount of the genetic diversity present in a given natural population can be represented in the collected sample.

Most cacao genetic resources are maintained as living trees in the field. Conservation in the form of field collections has the advantages that the growing material can readily provide budwood, seed or pollen needed for evaluation, as well as being available for characterization and on-going evaluation of their potential as well as training and demonstration. The field collections however are costly to maintain and are highly vulnerable to pests and diseases and other natural disasters such as floods, hurricanes and fires.

In vitro collections (as tissue culture on agar or other media in controlled growth conditions) are used mainly for safety duplication of the field collections and for rapid multiplication and dissemination of disease-free planting material. A drawback of *in vitro* conservation is that the material demands regular sub-culturing and might be subject to somaclonal variation. Therefore, rejuvenation and verification of the trueness to type of the conserved germplasm has to be performed periodically.

Cryopreservation, the storage of propagules in liquid nitrogen at ultra-low temperatures, is increasingly being used to enhance the security of germplasm collections and offers a complementary way to conserve cacao. Some success with cryopreservation of isolated immature zygotic embryos was reported (Pence, 1991). Efficiency of cacao somatic embryogenesis continues to be improved such that now, large numbers of somatic embryos can be generated from an increasing number of genotypes. An added benefit of the approach is that it can act as a barrier to the transmission of Cocoa Swollen Shoot Virus (CSSV): very few somatic embryos initiated from CSSV-infected trees receive virions and the transmission rate is further reduced following cryopreservation. More details can be found in Annex 4. .

Storage of frozen pollen samples may offer an additional way to conserve cacao, though the parent clone’s genetic identity would not be maintained.

2.2.2 *In situ* and on-farm conservation of cacao

In situ and on-farm conservation of cacao germplasm refers to the maintenance of cacao genetic diversity in its natural habitat or through the continued cultivation of landraces or traditional varieties in the agro-ecosystems where they have evolved. It therefore involves the protection of the areas, ecosystems and habitats in which the plants have developed their distinctive characteristics, and is facilitated through legislative and policy measures as well as the use of incentives. The great advantage of *in situ* conservation is that the evolutionary processes of the species and traditional varieties are maintained in a dynamic way.

However, significant deforestation activities, drastic changes in land use, climate change and associated natural catastrophes, rapid adoption by farmers of high yielding clones or human-made disasters are all contributing to the rapid erosion of genetic diversity, especially in the centre of diversity of cacao, the Upper Amazon.

One major cause of genetic erosion in this region has been the replacement of a broad range of traditional varieties by fewer introduced improved varieties. Although the newly introduced material is superior in performance, the rate of replacement is rapid causing losses of diversity not yet captured in *ex situ* collections.

Grafting is a common propagation method used in rehabilitation programmes. The introduced new clones (e.g. CCN-51 in Ecuador and Peru) are often bud-grafted on the regenerated young stems (chupons) of the old trees or planted in fields without shade under high input conditions. In some cases, only the inferior trees are budded with the new varieties, but in other cases, every tree on the entire farm is replaced. A similar trend is apparent in other regions in tropical America.

2.3 The current global *ex situ* conservation system

Since the early part of the 20th century numerous missions have been undertaken to collect and conserve cacao *ex situ*, in field genebanks. The early collections were based on clear objectives of identifying useful (i.e. resistant) types from the wild. More recently, the collecting missions have been focused on capturing the genetic diversity within geographically isolated populations.

In the 1970s and 1980s the International Board for Plant Genetic Resources (IBPGR), now Bioversity International, formally established a "Registry of Base Collections". Both the Cocoa Research Unit of the University of the West Indies (CRU/UWI) and the *Centro Agronómico Tropical de Investigación y Enseñanza* (CATIE) concluded agreements under the auspices of FAO ensuring that the designated germplasm become essentially public domain germplasm, that it is safely conserved for the long-term according to international standards and that it remain readily available to plant breeding programmes and other bona fide users. Recently, selected accessions held by these two international collections have been placed under the auspices of the Governing Body of the ITPGRFA. Only these two collections have accessions are available on the terms and conditions as defined in the Standard Material Transfer Agreement (SMTA)[4] of the Treaty. Although the international collections at CATIE and CRU/UWI have been supported by public and industry sources for many years, this support has not yet been secured for the long term.

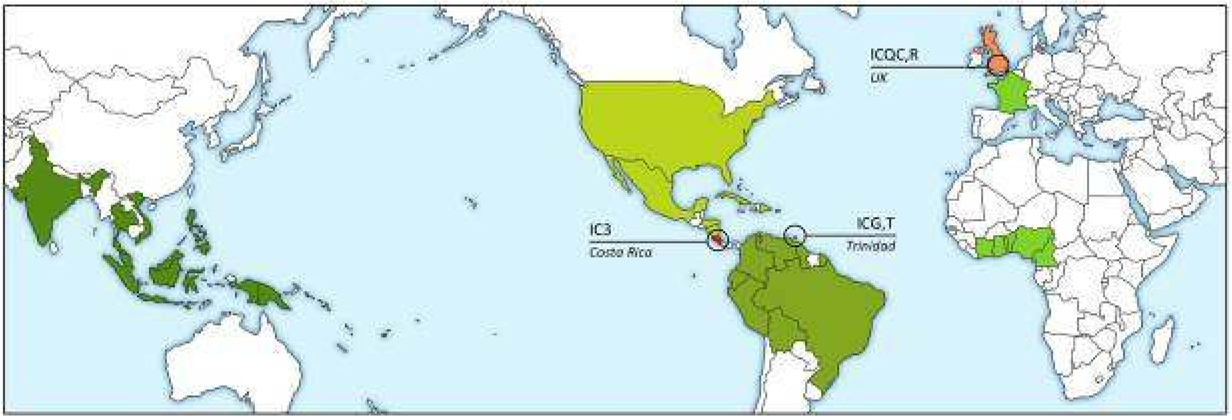
Between the two international collections at CATIE and CRU/UWI, duplication of materials is expected due to exchange and requests for interesting materials. But in addition to duplication between collections, duplication within collections is a major issue, mainly due to misidentification or lack of information to compare with similar accessions making it difficult to rationalize their management. A study by the International Cacao Germplasm Database (ICGD) at the University of Reading, UK, is being carried out and will shed some light on the situation. From the 35 collections for which the ICGD has information, it is estimated that 53% of the accessions (14,332 accessions) are maintained only in one location. An additional 10% are maintained in two locations. So the remaining 37% of accessions is maintained in

[4] See details at: http://www.planttreaty.org/content/what-smta

more than two locations with 23% of accessions maintained in more than five locations. Data from the ICGD in March 2012 indicate that the level of duplication between the two international collections at CRU/UWI and CATIE is of 268 accessions held in both collections, i.e. 11% of collection at CRU/UWI is also maintained at CATIE and 23% of CATIE collection is also maintained at CRU/UWI.

The International Cocoa Quarantine Centre at the University of Reading, UK (ICQC,R), was established in 1985. Although it is not a germplasm collection with conservation objectives *per se*, it holds cacao accessions available in the public domain and is the only international quarantine centre for the safe movement of cacao genetic resources throughout the world.

There are numerous national collections established at locations that are situated within the centre of diversity of cacao as well as in other cacao producing countries (See Figure 4).



Asia/Pacific	Americas	Africa/Europe
Fiji - Dobuilevu	Bolivia - El Ceibo Cooperative	Benin – CRA/SB
India - CPCRI	Brazil - CEPEC-SUEPA–SUERO-ICA	Cameroon - IRAD
Indonesia - Bah Lias-ICCRI	Colombia - CORPOICA	Côte d'Ivoire - CNRA
Malaysia - MCB	Cuba – EIC/ECICC	Ghana - CRIG
Papua New Guinea - CCI	Dominican Republic – IDIAF	Nigeria - CRIN
Philippines - USMARC/PICRI	Ecuador - INIAP	Togo - CRAF
Solomon Islands - BPCU	French Guiana - CIRAD	France – CIRAD
Thailand - CHRC	Guyana - MHOCGA	
Vanuatu - VARTC	Honduras - FHIA	**International collections:**
Vietnam - Nong Lam University	Mexico - INIFAP	Costa Rica - CATIE
	Nicaragua - UNAN	Trinidad & Tobago - CRU/UWI
	Peru - CEPICAFE–ICT-UNAS-UNSAAC	
	USA - USDA	**International quarantine:**
	Venezuela - INIA	UK - ICQC,R

Figure 4. Geographical distribution of the cacao *ex situ* collections.

An estimated 40 collections are known to exist. Table 2 herafter provides information on 36 of these *ex situ* collections with 32 who responded to the survey between 2008 and 2012 or 4 for which we had information from other sources. Together they maintain 24,370 accessions. There may have been different interpretation of what an accession is for cacao, by comparing numbers of accessions for each collection. The survey may not have been sufficiently clear. A proposed definition of an accession from Sackville Hamilton et al. (2002) is that in the case of plants conserved as clones, each clone will normally be managed as a separate accession.

The contact details of these collections can be found in Annex 3 and further information can also be obtained from the ICGD website.

Table 2. Number of accessions in cacao *ex situ* collections (Source: Data from the CacaoNet surveys 2008-2012).

Country	Institute	Date of info	Foundation Year of the collection	No. of accessions today
Benin	CRA-SB	March 2012	1986	15
Brazil	CEPEC-CEPLAC	June 2008	1967	1,302
Brazil	CEPLAC/SUEPA	May 2012	1965	2,504
Brazil	CEPLAC/SUERO	May 2012		773
Brazil	ICA	July 2011		130
Colombia	CORPOICA La Selva	FAO-VIEWS, 1998		745
Costa Rica	CATIE	February 2012	1944	1,146
Côte d'Ivoire	CNRA	August 2011	1973	1,605
Cuba	EIC-ECICC	June 2008	1982	127
Dominican Republic	IDIAF	July 2011	1974	115
Ecuador	INIAP	March 2012	1940	2,332
Fiji	Dobuilevu	SPC Dir. 2004*		115
France	CIRAD	February 2012	1985	138
French Guiana	CIRAD	February 2012	1980	508
Ghana	CRIG	August 2008	1943	1,366
Guyana	MHOCGA	July 2008	1920, 1950	65
Honduras	FHIA	March 2012	1987	31
India	CPCRI	July 2012	1970	291
Indonesia	Bah Lias	March 2012	1978	305
Indonesia	ICCRI	April 2012	1995	714
Malaysia	MCB	May 2011	1992	2,263
Nicaragua	UNAN	March 2012	2009	51
Nigeria	CRIN	August 2011	1948	1,100

Country	Institute	Date of info	Foundation Year of the collection	No. of accessions today
Papua New Guinea	CCI	August 2011	1994	1,200
Peru	CEPICAFE	March 2012		30
Peru	ICT	July 2012	1999	607
Peru	UNSAAC	March 2012	2000	72
Peru	UNAS	February 2012	1987	422
Solomon Islands	Black Post Cocoa Unit	SPC Dir. 2004*		95
Thailand	CHRC	March 2012	1979	34
Togo	CRAF	August 2011	1968	217
Trinidad and Tobago	CRU/UWI	April 2012	1982	2,400
United Kingdom	ICQC,R	February 2012	1983	395
United States of America	USDA	August 2011	1930**	200
Vanuatu	VARTC	SPC Dir. 2004*		85
Venezuela	INIA	February 2012	1994	872
36 collections			**Total**	**24,370**

* Directory of Plant Genetic Resources Collections in the Pacific Island Countries and Territories – Secretariat of the Pacific Community (SPC), 2004.

** 1930s, re-established in 2000.

Most of the national *ex situ* collections consist of locally selected genotypes belonging mainly to traditional varieties and introductions from the two international collections at CRU/UWI and CATIE. These collections provide an opportunity to screen for resistance to local pests and environmental adaptability.

The status of some of *ex situ* collections is poorly known. Except for the materials from CRU/UWI and CATIE, the germplasm is not brought under the aegis of the ITPGRFA since cacao is not one of the crops included on the Annex I list of multilateral system of exchange. Therefore, most of the material is subject to national legislations. However, in addition to the two international collections, some national collections can also be considered within the public domain, such as the collections at CIRAD and USDA. Unique and valuable material is conserved in national collections and thus, collaboration is needed to secure this material and increase the access to and their use in breeding programmes.

Effective management of cacao genetic resources includes the following activities:

1. Targeted collecting actions
2. Maintenance of key field genebank collections
3. Characterization and identity studies
4. Evaluation for important traits

5. Database management
6. Safe exchange of germplasm and all related information.

A survey to collect detailed information on *ex situ* collections was undertaken by CacaoNet between 2006 and 2012 to better understand the objective of the collections, their content (in terms of diversity), the long-term security of the collection, the management of the information, the exchange of materials and the urgent needs and priorities to be addressed through a global collaborative strategy. Annex 3 lists the institutes who responded to the survey. The *ex situ* conservation management activities are described in sections below based on information analysed from surveys.

2.3.1 Mandate and funding of institutes with *ex situ* collections

Most of the institutes surveyed have indicated that they have an official mandate from the government to carry out research on cacao and to conserve cacao at the national, regional or global level. Despite the mandates, only the two international collections have officially put their materials in the public domain and included in the International Treaty on PGRFA.

The main objectives stated by the cacao collections surveyed are the following:

- Conservation and management of genetic diversity of local, regional and introduced cacao.
- Widening the genetic base of cacao for breeding.
- Use of genetic resources for enhancing productivity, resistance to pests and diseases and quality.
- Documentation and dissemination of promising materials for research at national and international institutes.
- Distribution of elite material to the global cocoa community and particularly to farmers.

Despite the fact that many collections have stated a mandate to disseminate material at national but also at international level, very few of the collections provide access to the materials beyond national boundaries.

The current status of funding is inadequate for routine operations and maintenance, including buildings, facilities and equipment in 43% of the genebanks, for research on collection in 71%, for collecting germplasm in 85% and the number of trained staff is inadequate in 78% of genebanks. The level of trained staff is inadequate in 80% of collections. The situation is most critical regarding the funding for collecting (inadequate for 74%) and for research on the collections (e.g. characterization and evaluation, inadequate for 71%). Generally, the levels are grossly inadequate for the needs and the roles the genebanks are expected to play in implementing the Global Strategy.

In addition, it should be noted that even in the cases where funding is currently adequate, there is no long-term assurance securing this funding.

Despite funding and staff constraints, the level of use by breeders, researchers and growers is described as very good in 30% and adequate in 46% of the surveyed institutes.

2.3.2 Collecting germplasm

The wild germplasm in the existing *ex situ* collections was primarily acquired during a few collecting expeditions with the majority of them obtained from 1938 to 1943 (large number of seedlings collected from a limited of mother trees by Pound, 1945). These expeditions only covered a small fraction of the upper Amazon. The cacao germplasm collected prior to the early 18th century was based on small number of homozygous founders. Since that time, deforestation, diseases, pests and other stresses have speeded up the genetic erosion in the rainforest.

The catastrophic impact of cacao diseases in the early 20th century led to the expeditions to collect disease resistant germplasm from the Upper Amazon region in the 1930s. Since then several other collecting expeditions have been undertaken in the Amazon basin (see Table 3).

New collecting expeditions into the centre of diversity of cacao are necessary to fill diversity gaps in the genebanks.

Many of the surveyed institutes have plans for collecting. Some are planning to request material from the quarantine facilities such as the ICQC,R. Most are planning to collect materials from farmers' fields in their own countries. There is an interest from the following institutes to collect the following materials:

- Ecuador - more possible Nacional cacao ancestors
- CATIE - Criollo materials in Mesoamerica
- Ghana - Upper Amazon and Amelonado materials from farmers' fields
- Peru - River basins of the Madre de Dios, Ucayali, Urubamba, Huallaga, Putumayo, Purus and Marañon
- Trinidad – Colombia, Peru and Bolivia
- Venezuela - Cacao materials with Criollo characters in the state of Sucre, the north front coastal part where there has been presence of these materials.

Although the international and national collections in total contain a large amount of genetic diversity, recent expeditions have shown novel variability not contained within existing collections. This stresses the importance of *in situ* conservation efforts and the need to systematically sample areas with the objective of capturing novel variability within the cacao genebanks. A number of expeditions to sample the variability within the Amazonian home of cacao are at present underway in Brazil, Ecuador, French Guiana and Peru. Similarly, a World Bank sponsored project is exploring the total variability within the Trinitario population in Trinidad and Tobago.

Table 3. Cacao germplasm groups from major cacao collecting expeditions.

Major collecting expeditions	River basins	No. of mother trees
Pound collection (1938-1943)	Morona, Nanay, Ucayali, Maranon	32- 48
Anglo-Colombian collection (1952-1953)	Apaporis, Caqueta, Caguan Cauca, Infrida Negro, Putumayo Vaupes	191
IBPGR Bolivian collection (1974)	Rio Beli	21- 43
Brazilian collection (1965-1967; 1976 to 1991)	36 river basins including: Jari, Amapá, Maicuru, Pará, Jamari, Rondonia, Ji-paraná, Acre, Laco, Tarauacá, Purus, Japurá, Amazonas, Solimôes, Baixo Japurá	144 940 (and 877 from seedlings)
French Guiana collection (1987-1995)	Oyapok, Camopi, Euleupousing, Tanpok, Yaloupi	215
Chalmers collection, Ecuador (1968-1973)	Curaray, Coca, Napo, Putumayo	184
LCT EEN collection, Ecuador (1979-1987)	Curaray, Coca, Napo, Putumayo	255
ICA & IBPGR Colombian collection	Colombia	151
UWE Guyana collection (1998)	Guyana	31
Peruvian collection (1987-1989)	Ucayali	51
ICT-INCAGRO (Peru) / USDA collection (2008, 2009)	Santiago, Morona, Pastaza, Aypena, Ungumayo, Nucuray, Ungurahui, Marañon-Charupa, Nanay, Urituyacu, Chambira, Tigre, Napo.	342
INCAGRO(Peru)/USDA collection (2008, 2009)	Santiago, Morona, Pastaza, Nucuray, Nanay, Urituyacu Chambira, Tigre, Nanay, Urituyacu	324
Belize collection (1994)	Belize	52
Cacao Ancestors of the Nacional Variety Collection (CAN) (2010) (Silvestres Aromáticos)	Southern Ecuadorian Amazonia	71

2.3.3 Content of *ex situ* collections

Most genebanks have experienced growth during the past decade, through either collecting expeditions or germplasm introductions from other genebanks. The most significant increases since 2000 were in the collections from Malaysia (800 accessions), Papua New Guinea (1050 accessions), Côte d'Ivoire (1213 accessions) and Ecuador (1354 accessions).

Some material was also lost over the past 10 years such as in the case of the collections in: Nigeria (214 accessions), Ghana (200 accessions), Côte d'Ivoire (168 accessions) and Papua New Guinea (150 accessions).

Some collections also removed accessions as part of a rationalization or conscious reduction of the collection such as Papua New Guinea (300 accessions), Indonesia - Bah Lias Research Station (236 accessions), French Guiana-CIRAD (100 accessions), France-CIRAD (60 accessions), UK-ICQC,R (47 accessions), USDA (40 accessions), and Malaysia (30 accessions). Most collections experienced some degree of genetic erosion. Details are available in Table 4.

Most of the *ex situ* collections contain accession from wild types, landraces, and breeding lines. The survey requested information on number of accessions related to *Theobroma* species, of wild relatives, of wild *T. cacao* seedlings and of wild *T. cacao* clones. These amount to about 40% of the total estimated number of accessions.

The representation of secondary and tertiary genepools is very small within the various collections. The largest representation of these species is held in CRU/UWI, CATIE and CIRAD, in that order. There is also an important collection of *T. grandiflorum* in Brazil.

The collections that have a good part of their collection of local origin or native to the region are:

1. Venezuela – INIA (100%)
2. Ecuador – INIAP (98%)
3. Peru - UNSAAC (90%)
4. Papua New Guinea – CCI (85%)
5. Peru - UNAS (85%)
6. Peru – ICT (75%)
7. Brazil – CEPLAC/SUEPA (73%)
8. Brazil - CEPLAC/SUERO (72%)
9. French Guiana – CIRAD (72%)
10. Indonesia – ICCRI (69%)
11. Peru – CEPICAFE (60%)
12. Brazil - CEPEC-CEPLAC (56%)
13. Côte d'Ivoire – CNRA (55%)
14. Dominican Republic – IDIAF (50%)

The two international collections have the most material of regional origin: CRU/UWI (92%) and CATIE (75%).

Table 4. *Ex situ* collections and acquisition in the past 10 years (Source: CacaoNet survey 2008-2012).

Country	Institute	Date of info	No. of accessions today	Accessions acquired since 2000	Accessions lost since 2000
Benin	CRA-SB	Mar-12	15	15	0
Brazil	CEPEC-CEPLAC	Jun-08	1,302	418	10
Brazil	CEPLAC/SUEPA	May-12	2,504	233	96
Brazil	CEPLAC/SUERO	May-12	773	86	0
Costa Rica	CATIE	Feb-12	1,146	449	124
Côte d'Ivoire	CNRA	Aug-11	1,605	1,213	168
Cuba	EIC-ECICC	Jun-08	127	21	9
Dominican Republic	IDIAF	Jul-11	115	36	1
Ecuador	INIAP	Mar-12	2,332	1,354	17
France	CIRAD	Feb-12	138	25	30
French Guiana	CIRAD	Feb-12	508	30	10
Ghana	CRIG	Aug-08	1,366	300	200
Guyana	MHOCGA	Jul-08	65	0	0
Honduras	FHIA	Mar-12	31	0	0
India	CPCRI	Jul-08	291	130	9
Indonesia	Bah Lias	Mar-12	305	75	30
Indonesia	ICCRI	Jul-08	714	15	60
Malaysia	MCB	May-11	2,263	800	50
Nicaragua	UNAN	Mar-12	51	51	0
Nigeria	CRIN	Aug-11	1,100	296	214
Papua New Guinea	CCI	Aug-11	1,200	1,050	150
Peru	CEPICAFE	Mar-12	30	0	0
Peru	ICT	Mar-12	607	607	8
Peru	UNAS	Feb-12	422	262	2
Peru	UNSAAC	Mar-12	72	72	0
Thailand	CHRC	Mar-12	34	0	0
Togo	CRAF	Aug-11	217	189	32
Trinidad and Tobago	CRU/UWI	May-12	2,400	270	25
United Kingdom	ICQC,R	Feb-12	395	172	15
United States of America	USDA	Aug-11	200	4	10
Venezuela	INIA	Feb-12	872	404	0
		TOTAL	**23,107**	**8 465**	**1 285**

The collections that have 100% introduced materials (i.e. not native to the collecting country) are: Benin, India, Malaysia, Nigeria and Thailand. Nicaragua and USA have 90% of their collections as introduced materials. They are followed by Togo (85%), Ghana (78%), Guyana (70%) and Indonesia (Bah Lias) (60%).

Out of the total accessions surveyed, 3447 are clonal accessions selected in farms (15%), 3186 are seedling accessions collected from farms (14%) and 3297 are clonal accessions selected in breeding plots (14%). The ICG,T contains 50% of the samples from farmer fields from various cacao growing territories, in addition to a significant proportion (30%) of wild types. In contrast, in CEPEC/CEPLAC's and CIRAD's collections have a proportion of wild types in excess of 65%. The collections in India (CIPRI), CATIE and Cuba (EIC-ECICC) are rich particularly in breeding lines.

2.3.4 *Ex situ* collection management

Cacao genebanks, in addition to collecting and conserving genetic diversity within their jurisdiction, also have a responsibility to curate the collection at an internationally accepted level. This entails organizing the collection, safeguarding the collection from genetic erosion, duplicating the collection in fields or through cryopreservation of somatic embryos, characterizing the collection, documenting and sharing information so that the accessions can be utilized and sharing the genetic resources to support cacao breeding programmes worldwide.

From the institutes surveyed, 87% of reported accessions were maintained in field collections. Only a few institutes have accessions maintained *in vitro* such as Ghana - CRIG (68 accessions), UK-ICQC, R (15 accessions), Nicaragua - UNAN (5 accessions) and USDA (4 accessions). ICQC,R is the only institute with a few (12) accessions cryopreserved.

The survey of genebanks demonstrated that the level of genebank management varies widely depending on the country and the resources available. The value of a genebank is determined not only by how well the genetic resources are managed, safeguarded, shared internationally and utilized, but also to what extent the information generated from the genebank through characterization and evaluation is being managed and disseminated in a form that is meaningful to the end user.

All collections carry out field maintenance and labelling (routinely for 81% and occasionally for 19%), although half of the collections reported inadequate financial resources to support routine operations and maintenance, and particularly inadequate number of trained staff in 76% of cases.

Almost all collections reported existence of multiplication facilities (on site in 90% of cases and provided by a partner institute by 3%). Some collections however (31%) did not have irrigation facilities.

Over half of the collections have post-entry quarantine facilities either on site (30%) or provided by a partner institute (27%) and only a few of the collections (15%) carry out virus indexing. The institute that have virus indexing facilities on site are Côte d'Ivoire (CNRA), Ghana (CRIG) and Reading (ICQC,R). Indonesia (Bah Lias), Malaysia (MCB) and USA (USDA) have the virus indexing done by a partner institute.

Although field genebank establishment by rooted cuttings is the preferred option since it eliminates complications arising from root stock overgrowth or adverse stock-scion interactions, the rooting of cuttings is genotype-dependant. Only three institutes use rooted cuttings as a propagation method Côte d'Ivoire-CNRA, Nigeria-CRIN and CRU/UWI, albeit with great difficulty. Most of the collections (69%) use budded or grafted plants (under the cotyledon) as the main clonal propagation method, and 38% use budded or grafted plants (above the cotyledon) as the main method but extra care is needed to watch for rootstock outgrowth. Research on overcoming genotype-dependant rooting responses, as well as training efforts aimed at transferring propagation technologies to other genebanks is necessary.

2.3.5 Safety duplication of germplasm

When germplasm is not duplicated in a separate and distant location, it makes it extremely vulnerable to genetic erosion due to the risk of natural and man-made disasters. Cacao germplasm is vulnerable to disease threats, making the development of a Global Strategic Cacao Collection (GSCC) and its safety-duplication an immediate priority. It should be safely-duplicated at a distant location outside the country and preferably outside the region. Duplication through field genebanks remains a financially daunting proposition. Research and technology development in the area of *in vitro* conservation and cryopreservation is therefore vital.

The survey requested information on the status of safety duplication but the responses were somewhat confusing mainly due to the fact that the distinction between formal safety duplication (i.e. where an agreement exists between different institutes) and widely distributed germplasm (i.e. existing in several collections through dissemination) was not clearly made.

The survey revealed that 75% of collections do not duplicate their materials for safety, with only 6 collections with more than 50% of the germplasm duplicated at a distant location: CATIE (100%), France-CIRAD-MPL (100%), USA-USDA (95%), Brazil-CEPLEC/SUEPA (80%), Brazil CEPEC/CEPLAC (75%), and Guyana-MHOCGA (60%) (Source: Survey, Question 24). The survey did not request specific information on whether the distant location was within or outside the country or the region. The safety duplication of the material at CATIE was established during the period 2001-2005 by two sites at contrasting weather conditions and different altitudes (40 and 602 m.a.s.l.), and separated by 70 km. Also, part of the collection at CRU/UWI is duplicated at the ICQC,R where many of the quarantined accessions come from CRU/UWI. For the others however, it was not specified if the distant location is within or outside the country. And no information was requested on the type of agreement on the safety duplication.

The general opinion of experts is that very few collections have intentional safety-duplication through a formal agreement with another institute, outside of the country. The main reasons mentioned for the lack of safety-duplication agreements with other institutes is the limited funding, staff and planting area to maintain the collections and the lack of national policies for the conservation of cacao genetic resources. Further, many institutes do not have an official mandate for such responsibilities. Furthermore, pests/diseases were seen as a serious impediment to the overall welfare of the collections at CATIE, CEPEC/CEPLAC, USDA and CRIG, thus resulting in high levels of genetic erosion and severely constraining the ability to safely transfer germplasm.

2.3.6 Identification and characterization

Misidentification of trees within a genebank arising out of errors in establishment (due to various causes) or due to the root stock overtaking the scion is proving to be an important problem. The estimates of misidentification are much higher than initially thought and recent studies show that it can be as much as 30%. Lack of fidelity within collections can result in the errors being propagated through germplasm transfers around the world. DNA fingerprinting methodologies using microsatellites or simple sequence repeats (SSR) markers or Single Nucleotide Polymorphism (SNP) markers have been developed to uniquely identify trees. Many genebanks have begun fingerprinting the accessions at the tree level to understand the phylogeny of each tree and its relationship to other trees within the same accession plot. With the cost of fingerprinting decreasing over time, it is now feasible for verification of accessions at the individual tree level. This activity is carried out on a routine basis at the CRU/UWI, CEPEC/CEPLAC and USDA. Although a common set of SSR markers has been internationally agreed upon and can help to facilitate comparison of results obtained between different laboratories, there is still an urgent need for agreement on the composition of an international SNP set for genetic fingerprinting purposes. Following identification, each tree should be uniquely identified within the collection using permanent labels. The stock-scion unions are also being regularly painted to ensure differentiation between stock and scion material.

Characterization for taxonomic traits (flower colour, flush colour, pod, bean size, etc) is carried out on a routine basis in only 52% of the collections and occasionally in 37%. Characterization using molecular markers is carried out on a routine basis in only 6 institutes: CEPEC-CEPLAC, UNAS, ICT, CRU/UWI, ICQC,R and USDA, and occasionally in a further 15 collections. This may reflect the large percentage of institutions maintaining collections reporting inadequate financial resources for research and of facilities.

However, the majority of collections carry out field observations of disease and pest incidence and screening for pest and disease resistance. This reflects the objectives of the collections and the key traits of interest for breeding.

2.4 Genetic resources information management

A robust information management system is a key element in the conservation and use of genetic resources. At the most basic level, it is required to document accessions, including the number of plants and their physical location. When linked to characterization and evaluation data, these records allow breeders and researchers to make selections that may lead to farmers receiving improved planting material.

2.4.1 Local genebank management systems

Three CacaoNet surveys were conducted during the period from 2006 and 2012 in an attempt to assess the status of documentation for the various cacao collections. Questions were asked on the type of data collected on the accessions (passport, characterization, evaluation, distribution), how the data are managed (documentation tool), how the data are made available to potential users and what are the major plans, needs and constraints with regards to information management. This overview cannot be considered complete since not all of those collection managers contacted have returned the completed survey and/or provided a detailed list of accessions of material maintained. However, this exercise does provide some useful indications.

All genebanks collect some degree of evaluation and/or characterization data for the accessions held in their collection. Evaluation data were most commonly collected, primarily in the form of disease reaction observations. However, genebanks vary widely as to which data are regularly recorded, occasionally recorded or not recorded at all. For example, molecular marker profiles are available for the majority of accessions held in CRU/UWI, CATIE, ICQC,R and USDA, whereas many other genebanks have little or no genetic profiles for their collections. Many of the genebanks that have genetic profiles available for their germplasm keep records on which of their accessions, or individual plants of each accession, have been confirmed as true to type so that only these trees are used for re-propagation, distribution of plant material, characterization and evaluation.

The form in which data (passport, characterization, evaluation and management) is stored also varies between genebanks, with 50% using a database (often in combination with spreadsheets and paper records), 30% using only spreadsheets and 17% still relying on paper records. Even when collections are using a database for information management, the actual systems can be very different from one another (e.g. CRU/UWI uses MS Access and CATIE use DBGermo).

A common feature among local information management systems is limited availability of the data, both within the institutions themselves and for wider public access, since the majority are not online and many of the systems are restricted to access from a single location; even the databases are generally run on a single local workstation. However, several of the genebanks make their information more widely available, either on their own website or by submitting it to one of the international databases (see below), though only the USDA-TARS collection at Mayaguez indicated that accession information was directly maintained in a widely accessible online database (GRIN).

The surveys did not make a distinction between current data and historical information. It is likely that several genebanks have many years of data stored as paper records that have very limited access.

Genebank curators recognize the need for an information management system which could provide institute-wide access to data and images, and many wish to implement such a system in the near future. However, a lack of knowledge of germplasm and information management, staff and resources as well as facilities and equipment were listed as major constraints in progressing further.

2.4.2 Existing international cacao databases

Information on morphology, evaluation, origins and locations of a large number of cacao varieties (genotypes) can be found in the International Cocoa Germplasm Database (ICGD), University of Reading, UK, which is made freely available on the internet and on CD. All the information in ICGD comes from publications or has been supplied directly by research institutes and individuals. According to the survey, four institutes provide accession data to the ICGD regularly (once or more a year) and an additional 11 less than once a year (Source: Survey, Question 28) with 10 institutes not providing information to the ICGD, for a total of 25 replies to this question. The challenge is to obtain the complete accessions list of all cacao *ex situ* collections. More information is available on IGCD web site.

Genetic information on cacao, along with a range of other tropical crops, is available online through TropGENE hosted by CIRAD, a database that manages genomic, genetic and phenotypic information about tropical crops. The majority of data in TropGENE have been generated directly by CIRAD, though information has also been provided by several other institutions. More information is available on TropGENE website.

Clonal materials for field trials, MMSP nursery, Ghana (G. Lockwood)

CocoaGenDB is a database that comprises molecular genetic, genomic and phenotypic data developed through a collaborative project involving CIRAD, the University of Reading (School of Biological Sciences, UK) and USDA. This database combines molecular genetic information contained in TropGENE with phenotypic data contained in ICGD. This database allows complex queries to be performed, combining genetic and phenotypic information. The consultation web interface has to be specifically designed to allow end-users (breeders or molecular geneticists) to best exploit genetic information available on cacao germplasm. More information is available on cocoagendb website However, CocoaGenDB is likely to be replaced by web services in the next year or two, which will directly link the cacao component of TropGENE with ICGD.

Both ICGD and TropGENE (and therefore CocoaGenDB) contain information related to clonal material or varieties, rather than individual accessions in a collection, and may include data on unavailable material (e.g. germplasm that has not been placed in the public domain or has been lost). In addition, much of the data comes from a wide variety of sources and is measured in different ways, making standardization more difficult.

2.5 Utilization of cacao genetic resources

As mentioned earlier, cocoa is a crucial crop to 5-6 million farmers (mostly from small, family-run farms) who depend on it for their livelihoods, and the economies of their nations.

The future of the world cocoa economy depends significantly on the conservation and sustainable use of the broad genetic base. Compared to other crops, there has been limited investment into scientific research towards improving cacao, and only a limited number of practical breeders are involved in cacao breeding (e.g. seven in Africa, which produces 75% of world cocoa). Although evaluation of collections and farmers' selections has shown that wide variation for disease resistance and quality exist, most of the planting material given to farmers remains highly susceptible to prevailing diseases and pests. Furthermore, only a few varieties have been selected for sensory quality aimed at the specialty cocoa market. This underscores the importance of germplasm collections and their utilization through cacao breeding programmes towards supporting all stakeholders in the industry.

2.5.1 History of cacao breeding

The use of cacao germplasm for the selection of varieties with improved yield performance started as early as the beginning of the 20th century in some of the cacao producing countries. The identification of the "Imperial College Selections" (ICS) in farmers' fields in Trinidad in the 1920s is an important early example in cacao germplasm utilization. They are amongst the most widely distributed and utilized Trinitario cacao germplasm accessions. The destruction of cacao plantations in Trinidad in 1927 by the outbreak of witches' broom disease led to the search for genetic resistance in the centre of diversity of cacao. During 1930s-1940s, wild germplasm was collected from the Upper Amazon basin of Ecuador and Peru, which provided a much broader genetic variation for breeding.

In the 1950s, high yield potential was demonstrated in crosses between Upper Amazon Forastero and Trinitario or Lower Amazon materials. This formed the basis for cacao breeding programmes worldwide set up in the 1950s-1970s. Upper Amazon parents, such as indicated in Table 5 were introduced by cocoa producing countries from the Trinidad collection and usually crossed with local selections and/or a Trinitario selection, to create bi-parental crosses (hybrids) that retain traditional quality and improved yield, local adaptation and tolerance to existing pests and diseases. These bi-parental crosses are reproduced in seed gardens, mostly through manual pollination. It is noteworthy to mention that even Ghana, which has the best (although not perfect) set of seed gardens, cannot produce enough seed to satisfy demand.

Table 5. List of some important wild cacao germplasm from the Upper Amazon distributed since the 1950s, their utilization status and genetic notes.

Accession	Number of times used as parent[1]	Trees sampled leading to accession	No. of collections with accession[1]
IMC 47	M(0), F(1)	IMC group from 2 trees	19
IMC 60	M(3), F(3)		11
IMC 67	M(71), F(72)		38
NA 31	M(1), F(1)	NA group from 31 trees	7
NA 32	M(24), F(17)		14
NA 33	M(3), F(9)		22
NA 34	M(2), F(2)		14
POUND 7	M(16), F(7)	POUND group from 32 trees	28
POUND 12	M(3), F(3)		14
POUND 18	M(11), F(7)		8
PA 7	M(9), F(11)	PA group from 7 trees	16
PA 35	M(6), F(3)		15
SCA 6	M(113), F(77)	SCA group from 1 tree	39
SCA 12	M(37), F(48)		29

[1] Data obtained from Wadsworth et al. (2003) and ICGD (2007), M = acted as maternal parent, F = acted as paternal parent; other information from Lockwood and End (1993), Wood and Lass (1985), Bartley (1984), and Toxopeus and Kennedy (1984)

Table 5 only lists those widely distributed and commonly used Upper Amazon Forastero accessions. The listed accessions have been used in almost all breeding programmes in South East Asia, West Africa and Latin America They played a key role (as parental clones) in most cocoa-producing countries. This stresses the important contribution of the wild Upper Amazon germplasm, from Pound's collection, to the modern cacao breeding around the world. It is highly likely that there could be additional material from the Upper Amazon yet to be exploited and other populations to be sampled that could lead to a broadening of the genetic diversity in farmers' fields.

The selection criteria have evolved over time. While yield potential and adaptation to local growing conditions have initially been the main selection criteria in most breeding programmes, breeding for disease resistance has become increasingly important worldwide, although resistance can be considered an important aspect of yield as a protection against loss. Selections for resistance to CSSV and establishment ability have been major breeding objectives in West Africa since the 1940s. More recently, yield efficiency (dry cocoa yield divided by the stem section) has become an important trait to select less vigorous and more efficient cacao trees, e.g. in Papua New Guinea and Côte d'Ivoire. Recent selection for specific aromatic qualities has been undertaken in Trinidad (TSH clones) and in Ecuador (EET clones). Sensory quality is an important selection criterion in Ghana for example where cacao should taste like West African Amelonado (or West African cocoa) as well as in Trinidad (as part of a World Bank project), otherwise it is not considered acceptable for farmers' use. This criterion is becoming a more important selection trait also in other countries. Other selection criteria may arise in the near future such as polyphenol content and cadmium accumulation for example.

From the 1960s until the 1990s, breeding programmes aimed to obtain new bi-parental crosses whilst clone selection is increasingly receiving more attention, especially so in the America's and in South-East Asia. In Malaysia, Indonesia and Papua New Guinea the widely used planting materials comprised mainly crosses between Trinitario and Upper Amazon genotypes. Yield and disease tolerance for Vascular streak dieback were the main features of the recommended bi-parental crosses. However, outstanding clonal selections for yield and Vascular streak dieback resistance were obtained in the 1980s and 1990s. Cocoa pod-borer tolerance has become a major objective these cacao breeding programmes of South East Asian countries in the 2000s. The genetic diversity of the recommended clones is narrow for the latter trait, thus, there is a need to explore the potential of the accessions available in the germplasm collections in Malaysia and Papua New Guinea.

In a few countries (Brazil, Costa Rica, Côte d'Ivoire, Ghana and Papua New Guinea) recurrent selection programmes were initiated in the 1990s and 2000s. These programmes cannot be implemented without the availability of a large genetic diversity in the local germplasm collections and/or farmers' fields. The aim is to continuously improve the performance of bi-parental crosses or clone varieties simultaneously for yield, disease resistance and pod index. In Côte d'Ivoire, two cycles of recurrent selection were carried out between 1990 and 2010 in Upper Amazon and Lower Amazon (plus Trinitario) populations, before initiating reciprocal recurrent selection. The best intra-group crosses are currently being evaluated to be possibly released for commercial usage. The Mabang Megakarya Selection Programme initiated in 2005 in Ghana is the first stage of recurrent selection; the best clones will be used to generate seedling populations and the best seedlings will be tested as clones for their performance in an area affected by the devastating Megakarya form of Black pod disease (*Phytophthora megakarya*).

The West African Cocoa Research Institute (WACRI) further developed Hybrid Series I and II in the 1950s and 1960s, with the latter, involving crosses between Upper Amazon and local West African Amelonado or Trinitario making up the bulk of materials utilized by farmers. Later, crosses between Upper Amazon parents with higher tolerance to CSSV became predominant in Ghana. In Nigeria around 1972, 12 bi-parental were released that were specifically selected for establishment ability. Recently, eight new bi-parental crosses have been registered in Nigeria and released for farmers out of 23 that were tested. These crosses include Upper Amazon-Amelonado, Upper Amazon-Upper Amazon and Upper Amazon-Trinitario hybrids combining high yield, Black pod disease and mirid tolerance with good cocoa flavour quality.

In Brazil, a large breeding programme of Upper Amazon x Trinitario and Upper Amazon x Amelonado crosses was implemented between the 1960s and 1980s. Following the arrival of witches' broom (WB) disease in Bahia in 1990, a farmers' participatory approach was implemented to select for resistance on-farm simultaneously with on-station selection within germplasm collection and breeding populations. Several of the on-farm selections proved to be as good as the best on-station selections and the best are currently distributed as rooted cuttings and grafted plants.

Although cacao breeding was initiated a long time ago, only about 25% of all cacao plantations consist currently of improved varieties. Most farms are planted with traditional varieties (Amelonado, Trinitario and Nacional hybrid complex) or unselected varieties (e.g. open-pollinated Amazon populations and unselected seedlings derived from hybrid varieties). The main reasons being: firstly the under investment in seed gardens, secondly the inappropriate breeding methodologies and thirdly the breeders' disinterest in the means of proliferating of their best crosses.

2.5.2 Breeding for pest and disease resistance

Selection for pest and disease resistance in wild cacao populations has been one of the primary activities of cacao breeders and pathologists. Damage caused by major diseases and pests as well as breeding efforts carried out are summarized in Table 6.

Table 6. Major pests and diseases of cacao: causal agents, damage incurred and breeding efforts carried out.

Pest/disease	Causal agent and damage incurred	Breeding efforts
Witches' broom disease (WBD)	Caused by the basidiomycete *Moniliophthora perniciosa*, spread throughout all of South America, Panama and the Caribbean, causing great losses in production (e.g. in Brazil where the introduction of the disease in the region of Bahia caused a decrease in production of almost 70% during a period of 10 years).	Selection for resistance to witches' broom disease has been achieved in Trinidad and Tobago using accessions from the Pound collection. Breeding programmes in Brazil have also had this objective since the outbreak of the disease in the 1990s.
Frosty pod rot or disease (FP)	Caused by the basidiomycete *Moniliophthora roreri*, significant losses in production, even resulting in the abandonment of cacao farms in Mesoamerica and regions of Ecuador and Venezuela and it is continuing to spread rapidly in the region.	Resistance to frosty pod has been successfully achieved in clonal cultivars selected by CATIE in the 1990s and early 2000s, based on resistant accessions identified in the collection.
Black pod (BP) or *Phytophthora* pod rot (Ppr)	Caused by *Phytophthora* spp. (*P. palmivora, P. megakarya, P. capsici* and *P. citrophthora*). *P. palmivora* causes global yield loss of 10-30%. *P. megakarya* is the most important pathogen in Central and West Africa, known as the most aggressive of the Ppr pathogens. *P. capsici* and *P. citrophthora* occur in the Americas, causing significant losses. Cultural practices and spraying campaigns can be ineffective in controlling *P. megakarya*, and this has led to the abandonment of many farms in Central and West Africa.	Resistance to black pod has been evaluated in the Trinidad and Costa Rica collections. The French Guiana collection was also totally evaluated for resistance to *P. palmivora* and *P. capsici* (results to be published). A large pre-breeding programme has been implemented since 1995 by the CRU/UWI in Trinidad, using the genetic diversity present in the CRU/UWI. Breeding for black pod resistance is currently a major aim in Africa, Papua New Guinea and Trinidad.

Pest/disease	Causal agent and damage incurred	Breeding efforts
Vascular-streak dieback (VSD)	Caused by the fungus *Oncobasidium theobromae*, found in South East Asia, causing major losses in particularly in Indonesia, Malaysia and PNG.	Resistance to vascular-streak dieback was successfully selected for in the field in the 1980s and 1990s in Malaysia, Indonesia and in Papua New Guinea. Parental lines with vascular-streak dieback resistance have been incorporated in breeding programmes in these countries.
Cocoa Swollen Shoot Virus (CSSV)	Caused by a small non-enveloped bacilliform virus transmitted by at least 14 species of mealy bugs and is present in the forest regions of West Africa. Major damage has been in Ghana, Togo and Nigeria and recently in Côte d'Ivoire. Eradication of diseased trees has been the main control method.	Selection for resistance to the spread of Cocoa swollen shoot virus in Ghana started in the 1940s, relying on Upper Amazon materials introduced from the Trinidad collection.
Insects – Mirids and Cocoa pod borer (CPB) (also known as Cocoa moth)	- Mirids are insect pests that affect cacao worldwide, but are a major pest in Africa. Mirid damage alone, if left unattended for three years, can reduce yields by as much as 75%. - Cocoa pod borer is caused by the insect *Conopomorpha cramerella*, affects cocoa production in Malaysia, Indonesia and Papua New Guinea. The high cost of control of cocoa pod borer along with the decline in the price of cocoa in the 1990s and early 2000s and the lower profitability led to a significant decrease in production in Malaysia.	Selection for resistance to insects (mirids, cocoa pod borer) has not yet been successful, as variation for resistance is limited or difficult to assess in collections and breeding populations. However, recently some progress has been obtained.

Besides traditional breeding efforts to create pest and disease resistant varieties, recently much information has been obtained about the association of molecular markers and disease resistance genes, especially for resistance to black pod, witches' broom disease and frosty pod. The advances in these areas of research have made it possible to start using the molecular markers to carry out Marker Assisted Selection (MAS). This technique is currently being applied in West Africa, where marker assisted screening is carried out of individuals in segregating populations with resistant parental clone background, with support from a USAID/USDA/Mars funded project.

Since 1996, CRU/UWI has been executing a germplasm enhancement or pre-breeding programme for black pod resistance. The idea behind this programme was to increase the frequency of resistance alleles in selected germplasm populations. Based on the evaluation data, it was demonstrated that about 10% of the ICG,T accessions are moderately resistant or resistant to black pod. Some populations carry a higher frequency of resistant accessions than others. The outstanding accessions within different genetic groups (Trinitario, Refractario, Upper Amazon types) were crossed amongst each other and the seedlings produced were screened again for the same trait. The first cycle of seedling selections has been planted in the field and is being evaluated for several traits. The most outstanding selections for black pod resistance are being sent to intermediate quarantine for distribution to interested user countries. A similar programme was initiated at CRU/UWI for witches' broom disease resistance in 2005.

The collection of CATIE has been used directly in a regional breeding programme since the 1970s. Initially, the objective of the CATIE breeding programme was to select elite bi-parental crosses using parents from the collection with good combining ability for yield. However, these proved to be generally highly susceptible to frosty pod, which arrived in Costa Rica in the 1980s. Since the mid 1990s the main objective has been to select productive clones with accumulated resistance to frosty pod, based on crosses amongst the few resistance sources that were identified from within the CATIE collection and breeding populations. CATIE has released six clones for commercial planting in Central America since 2005. A new cycle of clone selections has been initiated in 2007. CATIE has identified clones having simultaneously a resistant reaction against both black pod and frosty pod. In Ecuador, new sources of resistance to frosty pod were identified in the 2000s.

The impact of using disease resistant wild germplasm in cacao breeding has been important. Among the various upper Amazon wild cacao germplasm, two Peruvian accessions, 'SCA 6' and 'SCA 12', have been extensively used in breeding programmes due to the high yield of their progenies and their resistance to witches' broom disease and black pod, even though they are very susceptible to frosty pod. At least 300 improved varieties or advanced breeding lines (clones or hybrids) have been selected from progeny of these two clones. However, a strong location effect was also observed in SCA clones and their derived progenies, with breakdown of witches' broom disease resistance in Ecuador and Brazil. Fortunately, it has been demonstrated that robust resistance to witches' broom disease exists also in other Forastero germplasm groups, such as in the wild germplasm collected from the Jamari, Acre, Javari, Solimões and the Purus river basins in Brazil, in the Chalmers and Allen collections of wild materials from the Ecuadorian Amazon regions, and in several of the populations held by the ICG,T. Further exploration of resistance from such germplasm groups is essential to expand the genetic background of witches' broom disease resistances and obtain more durable resistance.

2.5.3 Breeding for quality traits

Some of the traditional cacao populations are well known for their fine flavour profiles. Such is the case for ancient and modern Criollo varieties (with sweet and nutty flavours), Trinitario (fruity flavours) and Ecuadorian Nacional ("arriba" mainly floral flavour). Selections were made within these varieties in Venezuela, Trinidad and Ecuador. These were placed in collections and the best were recommended for use by farmers, such as the ICS1, 6, 8 and 95 clones in Trinidad from the 1930s onwards and ten EET clones in Ecuador from the 1970s onwards.

More recent research results have shown that high flavour quality can also be identified in Forastero cacao populations. One well-known Upper Amazon Forastero clone with brown-fruit and floral flavour is Scavina 6 (SCA 6), though the bean size is small. Some cultivated cacao populations derived from spontaneous cacao in the Amazon have also shown interesting flavour attributes, such as "Porcelana" cacao south of the lake Maracaibo in Venezuela, "Chuncho" cacao in the Cuzco area in Peru, and the Bolivian "Nacional" varieties.

Improved clone (C. Montagnon).

Until recently, breeding has aimed at maintaining the known local quality characteristics in selected varieties. The selection of TSH clones in Trinidad, between 1970 and 2000, aimed at combining disease resistance with good quality. Several of the new TSH varieties possess interesting flavour profiles, derived from Trinitario but also partly derived from Forastero parental clones (such as the brown fruit and floral flavours inherited from SCA 6). In Ecuador, recent cacao breeding has involved crosses between Nacional clones and the highly productive CCN51 clone, aiming at combining high yield potential with "arriba" flavour as well as disease resistance. In Brazil, several of the clones selected for witches' broom disease resistance are apparently interesting also for specific flavour traits. Over the last eight years the CATIE´s breeding programme has significantly increased selection pressure for quality traits with some clones already identified with high yield potential, resistance to frosty pod and black rot, and a good quality profile. Future studies on the evaluation of genebank accessions and other wild cacao populations for flavour traits would be useful. Ecuador has an ongoing research for sensorial characterization of some accessions of the Chalmers collection.

The use of germplasm in breeding programmes however remains limited by our understanding of it. Bartley stated 57 years ago that "the performance of bi-clonal hybrids is not related to the performance of the parents as clones". Genetic experiments have shown that key traits such as yield and vigour are inherited additively and yet the phenotype is no guide to the genotype. Repeated observations at BAL Plantations showed that converting seedlings to clones reduces the vigour by about 40%, and that this effect is reversed when the clones are used to produce seedlings. Observation plots at Mabang have confirmed that the same effect is found in Ghana, at least for seedlings converted to clones, and it applies across a wider genetic base (G. Lockwood, pers. com.). Therefore work is needed for a better understanding of the best breeding approach which will impact on the capacity to select the best materials to breeders.

2.5.4 Evaluation of germplasm

Introduction of new accessions from international collections into local collections is best guided by the results from evaluation for economically important characteristics (yield, disease resistance, establishment ability, precocity and quality).

An example of a project aimed at strengthening the evaluation and exchange of promising materials has been the creation of a collection from the CFC/ICCO/Bioversity project. This collection of around 110 accessions was selected in Trinidad in 2002-2004 for its genetic diversity and each accession contains at least one favourable agronomic trait (mainly disease resistance) which makes it worth introducing into national collections that need to be reinforced for such traits. The CFC/ICCO/Bioversity project collection was virus-indexed at ICQC,R between 2005 and 2010 and distribution to user countries has been initiated.

In 2009, following the same procedure, the USAID/USDA/Mars project has introduced specific groups of clones into cocoa producing countries in West African producing countries (e.g. Côte-d'Ivoire, Ghana, Nigeria and Cameroon). The main objective was to share responsibilities for the introduction and evaluation of germplasm that has not been explored or exploited for genetic improvement purposes. In addition, the INGENIC-West African Cocoa Breeders Working Group has also been involved in the introduction of some clones with known resistance to major threatening diseases such as the witches' broom and frosty pod rot from ICQC,R.

The INGENIC Asia-Pacific Regional Group has been actively undertaking cacao breeding activities through the exchange of selected hybrids and clones focusing on high yield and tolerance to cocoa pod borer and vascular-streak dieback. In addition to the evaluation of 14 selected bi-parental crosses and 6 clones in each participating institution, new activities that include selection of new parental clones and assessing the flavour aspects of the exchanged materials will be undertaken. In the future a new set of crosses will be exchanged and also a similar set of activities as in Africa will begin by the introduction and evaluation of non-explored germplasm.

Another example of germplasm collection evaluation is at CPCRI, India, where 216 accessions from the germplasm collection have been screened for drought tolerance looking at the leaf morphology, water relation-components, stomatal behaviour, photosynthesis and biochemical factors. Based on these characteristics 10 drought tolerant accessions have been identified. Breeding for drought tolerance using high yield and drought tolerant trees have resulted in some promising hybrids which showed similar traits. From the field trials of these parents and hybrids, three hybrids have shown drought tolerant traits with high yields.

Almost all of the collections surveyed carry out yield evaluations (pod and bean traits) and field observations of disease resistance routinely (64%) or occasionally (36%), indicating an active interest in utilization of the genetic resources.

However systematic evaluation of *ex situ* collections for important traits has only been partially achieved. Uptake of accessions in breeding programmes has been limited, partly due to the lack of information on the traits of the accessions or the lack of reliable evaluation methods, especially so for yield traits and pest and disease resistance.

Of the collections surveyed, 16 institutes carry out breeding on a routine basis (Source: CacaoNet survey, Question 26). These are:

1. Brazil-CEPEC-CEPLAC
2. Brazil-CEPLAC/SUEPA
3. Brazil-CEPLAC/SUERO
4. Costa Rica-CATIE
5. Côte d'Ivoire-CNRA
6. Cuba -EIC-ECICC
7. Dominican Republic-IDIAF
8. Ecuador-INIAP
9. Ghana-CRIG
10. India-CPCRI
11. Indonesia-ICCRI
12. Malaysia-MCB
13. Nigeria-CRIN
14. Peru-ICT
15. Peru -UNAS
16. Togo-CRAF

The following institutes carry out breeding activities occasionally:

1. Indonesia - Bah Lias
2. Papua New Guinea - CCI
3. Thailand - CHRC
4. USA – USDA/ARS-Miami
5. Peru - INIA

The cacao genebanks disseminate materials to farmers occasionally in 50% of cases and regularly in fewer cases (25%).

Uptake of genes from the national collections in farmers' fields has been verified in Cameroon, Côte d'Ivoire, Ghana and Nigeria by carrying out genetic diversity studies of farm accessions compared to the diversity present in collections using SSR markers. The results show relatively low levels of selected varieties in farmers' fields (with the exception of Ghana), although the genes present in collections were well presented in farmers' fields. This is explained mainly by the common practice where, due to the low availability of seed of selected varieties, farmers make use of open pollinated seeds from their own plantation or from their neighbour's plantation. High adoption rates of selected varieties have been observed in other countries with strong breeding programmes and efficient systems for hybrid seed production or clonal propagation, such as in Brazil, Ghana, Papua New Guinea and Malaysia.

The main limiting factors mentioned by the collection curators for the germplasm to be used in breeding are: (1) lack of information and knowledge (particularly evaluation) on the materials, (2) constraints in accessing materials (quarantine and policies), (3) relative narrow genetic base available, (4) few breeding programmes and breeders and (5) lack of funding for research and breeding programmes.

As mentioned, a key factor in whether germplasm becomes utilized, rather than simply conserved, is the availability of useful information. For example, data from seedling trials would provide invaluable information on the genetic values of accessions, making a significant contribution to breeding. Although several systems exist or are being developed that aim to provide the cocoa research and breeding communities with access to such data (see Sections 2.4 and 3.7), there is still a large amount of information that has yet to be widely disseminated. This is particularly true for older, paper-based documents, which would often have been simply stored in offices or warehouses, with potentially little record of their existence. Efforts are being made to rescue these historical records, such as in Ghana, Malaysia (G. Lockwood, pers. com.) and Brazil (U. Lopes, pers. com.), but this type of data is likely to exist in most countries where such rescue efforts are not being reported.

2.5.5 Involvement of farmers in breeding

Farmers do not hold any "collections" but actively contribute to the selection of new clonal cultivars in their own plantations. An example is the selection of hundreds of clones with resistance to witches' broom disease by farmers in the Brazilian State of Bahia in the 1990s and early 2000s. In the early 2000s, a farmers' participatory approach in the cacao breeding programme was adopted in West African countries. The programme started with a farm survey during which pods and budwood were collected from trees that were considered by the farmers as promising for high yield and low black pod incidence. Trees selected by farmers for low black pod incidence have been confirmed as more resistant using the leaf disc tests. In addition, demonstration plots were established in farmers' fields by breeders and farmers to assess promising material from farmers' fields and validate the performance of new varieties in farmers' areas. In 2002, the Australian Centre for International Agricultural Research (ACIAR) and Mars started testing farmers' selections in Sulawesi.

Farmer's selected grafted clone, Venezuela (A. Eskes, CIRAD/Bioversity).

From more than 300 screened clones, 20 are now in the second round of replicated trials for final evaluation. One of the selected clones is very high yielding and is already being used by Sulawesi farmers. The second phase (2004-2009) of the CFC/ICCO/Bioversity project on "Cocoa Productivity and Quality Improvement: a Participatory Approach" had as objectives:

1. To validate promising cocoa varieties in farmers' fields through participatory approaches,
2. to increase sustainability in cocoa crop improvement programmes through validation and dissemination of selected cocoa varieties between partners,

3. to exchange information and disseminate results,
4. to establish and maintain functional linkages between national breeding programmes, international genebanks and quarantine centres, and international research and development efforts. These examples show that the farmers' knowledge of their own planting material can also be successfully exploited to carry out selection and breeding activities in a participatory manner.

2.5.6 Multiplication for planting materials

Current techniques used to provide new planting material to farmers include farmer nursery, seed gardens and seedling supply, multiplication of clones via patch, bud, top grafting, rooted cuttings, side grafting and via tissue culture and are described below:

- Farmer nursery: Some farmers will set up a small nursery (i.e. using seed from their own selection on their own farm or a neighbour's farm), and will often select the most robust seedlings for replanting areas of their farm. This can be widely seen in Ghana, Côte d'Ivoire and Nigeria.
- Seed gardens: Selected bi-parental crosses are mainly multiplied in mono-clonal or bi-clonal seed gardens, using manual pollination. Open-pollination of self-incompatible female parents, as practiced in the past in some countries, has proven to be unreliable, due to the ineffectiveness of the self-incompatibility mechanism as well as vegetative imbalances between the clones. However, there is lack of sufficient seed gardens in many areas, whilst seed production systems in some countries are inoperative or inadequately managed. Seed gardens and seedling supply are used in Ghana by the Ghana CocoBod Seed Production Unit, which produced 6.9 million seed pods in 2010/11, and is also used to an extent in Côte d'Ivoire, Indonesia (ICCRI) and the Dominican Republic.
- Clones via patch, bud or top grafting: Clonal plants can be produced by grafting an improved variety onto a non-selected, or bi-parental cross rootstock. This is usually carried out professionally and supplied to a farmer as a plant. Budwood gardens can be used to generate material for grafting. These techniques are used in Indonesia, Vietnam and Papua New Guinea.
- Clones via rooted cuttings: Explants can be taken from a selected, improved variety and induced to root. This is normally carried out professionally and the young plants are supplied to farmers, for example by BioFabrica in Brazil and by the Ministry in Trinidad. Some studies suggest that the superficial root system of cuttings makes these suffer more from drought than grafted plants. Clones vary immensely in ease of rooting. For example, ICS1 is notoriously difficult to root. For example, in tea selection, the first step is to establish that a candidate is easy to root, but this has not been done in cocoa (G. Lockwood, pers. com.).
- Clones via side grafting: budwood from an improved, selected variety can be grafted onto the trunk or chupon of a mature tree. This technique is used for example in the Sulawesi ACIAR project and in Mars Vision for Change (V4C)

project in Côte d'Ivoire. Once the graft "takes", the older part of the tree can be cut away.

- Clones via tissue culture: The induction of somatic embryogenesis in cocoa explants and maturation of these embryos into plantlets is a laboratory based procedure to bulk up a selected, improved variety. The plantlets are weaned under nursery conditions and supplied to farmers as young plants. This technique is used by Nestlé Tours working with institutes in Ecuador, Indonesia (ICCRI) and Côte d'Ivoire, Penn State University (trials), Almirante farm in Brazil. Recently, vegetative propagation through somatic embryogenesis has been used on a large scale in Indonesia. This experience suggests the potential application of this new technology in other cocoa producing countries.

Bioversity is currently leading a study by industry experts to assess these cacao propagation methodologies and subsequently develop strategies to supply quality planting material to farmers, adapted to the conditions and needs of specific countries.

2.6 Cacao germplasm exchange

As previously highlighted, a considerable range of cacao genetic diversity is currently held in national and international genebanks, but access to these resources is often restricted by the lack of a clear institutional legal and policy framework for the exchange of materials, or due to pest and diseases affecting the germplasm and its safe movement.

2.6.1 Benefits of sharing cacao genetic resources

Recent years have seen an acknowledgement of the growing value of plant genetic resources for food and agriculture, owing to both the development of new powerful technologies to realize their potential and the knowledge that they are not an unlimited resource. As a consequence, issues related to access and benefit-sharing, the security of the material and the ownership of collections are the subject of continuing debate.

Most of the national programmes are operating under the premise of the Convention on Biological Diversity (CBD), usually without having specific Access and Benefit Sharing (ABS) legislation in place. This situation has resulted in fragmented approaches, informal exchanges of germplasm and thus, the benefits that are generated in germplasm providing countries are not recognized, at least not to those authorities that make policy decisions in the respective countries.

Through discussions with genebank curators and researchers worldwide several aspects of cacao germplasm exchange have been identified as actual or potential benefits for the world cocoa economy at large and particularly to countries contributing genetic resources to the global system.

The main benefit of taking part in a global system for the conservation and use of cacao genetic resources is the actual continued and facilitated access to a broad range of cacao diversity for all bona fide users. This is the essential element in the production of new and improved cacao varieties to achieve sustainable and economical production and thus, contributing to the economy of cacao producing countries. Great benefits can be generated from global collaboration and the sharing of these key genetic resources and particularly the following:

- Facilitated access to materials such as: (1) evaluated germplasm, i.e. material that can be directly included in national and local selection trials, as well as in breeding efforts; (2) enhanced breeding populations, i.e. populations with enhanced value for agronomic traits (in particular disease resistance) that were selected by using the wide genetic variation available in international germplasm collections, and (3) healthy germplasm and/or use of plant quarantine services, including the development of local/national quarantine facilities, reducing the spread of cacao pests and diseases.
- Increased access to information and knowledge on cacao genetic resources worldwide so that more advantages can be obtained from the improved information management systems, including strengthening institutional and national systems (e.g. new specific software, programmes and information technologies, or management of molecular genetics data and bioinformatics).
- Technologies, procedures and methods to conserve, improve and breed cacao. Long-term conservation of germplasm methodologies including cryopreservation, characterization standards, network of evaluation, diversity analysis, genetic tools, and somatic embryogenesis.
- Strategic alliances and partnerships: collaboration in research, breeding, DNA analysis and interpretation/application; Clarifying the legal status of cacao collections, including formal roles and responsibilities of national cocoa research institutes in conserving and developing cacao germplasm collections; Developing transparent ABS arrangements for cacao genetic resources. New opportunities for funding and collaboration will emerge through participation in and acceptance of international obligation and commitments.

2.6.2 Safe movement of germplasm

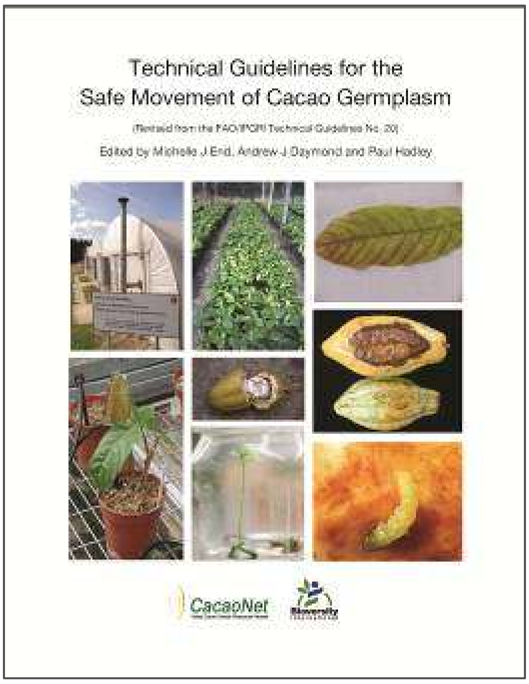
Although essential to the utilization of cacao genetic resources, movement of cacao germplasm brings with it the potential risk of transferring pests and diseases. This is particularly the case when germplasm is moved from one major cacao-growing region to another, since many of the pests and diseases of cacao are geographically isolated. The recent spread of *Moniliophthora* pod rot (frosty pod rot) within Central America, the movement of cocoa pod borer into Papua New Guinea from elsewhere in

Collecting budwood for germplasm transferring, CATIE, Costa Rica, (W. Phillips, CATIE).

South-East Asia, and the cryptic nature of mild strain viruses are illustrative of why high levels of precautions are needed when moving cacao material. This is the case whether it is between regions, or within a country. It is essential therefore that all those involved in handling cacao genetic resources have access to information highlighting the risks associated with each particular pest or disease and recommendations on appropriate quarantine measures.

Currently the safe movement of germplasm at the global level, including virus indexing, is achieved through the International Cocoa Quarantine Centre at the University of Reading, UK. The USDA/ARS facility in Miami, USA, offers quarantine facilities for regional transfers.

The CacaoNet Safe Movement Working Group agreed that a priority action should be to update the Technical Guidelines for the Safe Movement of Cacao since the last edition, published by FAO, is over 10 years old (Frison et al., 1999). The revised Safe Movement Guidelines (CacaoNet, 2010) were compiled under the auspices of CacaoNet with the aim of including a description of a much more extensive range of pests and diseases, up-to-date information on all the pests and diseases featured and additional information on quarantine measures.



The 2010 Safe Movement Guidelines document deals with movement of germplasm for research, crop improvement, plant breeding, exploration or conservation. Broadly speaking, the document sets out to convey the following:

- General advice regarding safe procedures to use when moving cacao.
- The geographical spread of significant pests and diseases of cacao.
- A description of the key features of pests and diseases.
- Quarantine advice in relation to moving germplasm from a region where a specific pest or disease may be present.

The publication of Frison et al. (1999) was used as a base document, although expanded to include sections on intermediate and regional quarantine centres, general recommendations for cacao germplasm movement and risks associated with movement of different plant parts. A summary table of pest risks provides the reader with an overview of the geographical spread of pests and diseases of cacao and special precautions needed when moving particular plant parts. There is also a table summarising pest and disease risks by country. The document then includes detailed descriptions of pests and diseases of cacao. Each of these sections was compiled or updated by relevant experts whose input is acknowledged. The pests and diseases covered in the document are virus diseases (CSSV, Cocoa yellow mosaic virus), fungal diseases (witches' broom disease, frosty pod, black pod, vascular streak dieback, *Verticillium* wilt, *Ceratocystis* wilt, *Rosellina* root rot), insect pests (cocoa pod borer, mirids/capsids, mosquito bug, other insect pests) and nematodes. Each description on a given pest or disease includes, as a minimum, a description of symptoms (including detailed photographs), current information on its geographical distribution, an overview of key features of the biology of the pest or disease, quarantine measures recommended and a source reference list.

Germplasm should be obtained from the safest source possible, e.g. from a pathogen–tested intermediate quarantine collection. Region to region transfer of budwood should usually take place via a quarantine centre. Post entry quarantine stations are present in some cocoa-producing countries and are used primarily for material newly imported into the country in question. The length of time in post-entry quarantine can vary from six month to two years. In some cases, post-entry facilities are also used for within country movement of germplasm.

The transfer of germplasm should take place in consultation with the relevant plant health authorities in both the importing and exporting countries. International standards for phytosanitary measures as published by the Secretariat of the International Plant Protection Convention (IPPC) should be followed. In accordance with IPPC regulations, any material being transferred internationally must be accompanied by a phytosanitary certificate.

According to the genebanks surveyed, only half of the collections carry out quarantine of incoming/outgoing material on a routine basis. Viral diseases are a particular threat to the safe movement of germplasm since they cannot be eliminated and, moreover, can remain latent (symptomless) in some genotypes. The pesticide treatments are usually applied to germplasm before it is exchanged. As mentioned, only a few of the collections carry out virus indexing and those that have facilities on site are: Côte d'Ivoire (CNRA), Ghana (CRIG) and Reading (ICQC,R). Indonesia (Bah Lias), Malaysia (MCB) and USA (USDA) have the virus indexing done by a partner institute. This may be because some of the materials are coming from quarantine centres such as ICQC,R where post-entry virus indexing may not be necessary.

The presence of viruses in collections can therefore impact on the genebank's ability to distribute germplasm, as can high levels of pests and diseases which can reduce the vigour of trees and thus the availability of suitable budwood/seed pods, in addition to increasing the risk of transferring infected materials. Several genebanks reported that pests/diseases were limiting/preventing them from distributing germplasm including those in Brazil, Costa Rica, Dominican Republic, Ghana and Indonesia, Nigeria, Peru and Togo.

Pest and diseases preventing distribution of germplasm have a major effect for the collections of Brazil, Costa Rica, Dominican Republic, Ghana, Nigeria, Peru and Togo.

2.6.3 Distribution of germplasm

At present the global arrangement for the exchange of cacao genetic resources relies mainly on the two international collections held by CATIE and CRU/UWI that have formally placed their cacao collection under the auspices of the Governing Body of the International Treaty. Other collections, such as the one in CIRAD (Montpellier and French Guyana) and USDA, also make their materials available for international distribution. With the exception of these collections, there is little international exchange of germplasm.

The surveys show that only 25% of genebanks regularly distribute germplasm to local users (once or more every month). A further 46% distribute occasionally (less than once a month but at least once a year) and 29% rarely distribute to local users. The percentages decrease for distribution of germplasm to users outside the country and outside the region.

The average number of accessions distributed annually varies greatly from a few pods to 300 and in some cases no information is recorded on distribution. The surveys show that locally collected accessions are distributed locally in the majority of cases and distributed outside the country only in the few collections that have mandates for international distribution.

Furthermore, there was little evidence of any genebank obtaining feedback from the countries to which germplasm was sent. This may be due to the high probability of misidentification making the reports unreliable. Therefore the identification at tree level and the establishment of a proper traceability system through the intermediate quarantine to the final destination is very important. Another reason might be that the linkage between the originating genebank and the final beneficiary country is weakened by distributions out of the intermediate quarantine without any regard to the originating genebank. This linkage could be strengthened if a MTA were to be issued by the intermediate quarantine centre on behalf of the originating genebank and the MTA returned to the originating genebank. For the material coming from CATIE and CRU/UWI, the Treaty Standard Material Transfer Agreement (SMTA) is used and should be passed on to any third party. The ICQC,R is using the SMTA to distribute material received from CRU/UWI and CATIE. In the case of material received from other collections, the ICQC,R uses their own MTA requesting the donor genebank to confirming that they agree for the material to be passed on to a third party.

The purpose of the disseminated germplasm, according to the surveys, is mainly for evaluation, breeding and research activities (taxonomy and related studies).

The factors limiting the use of new germplasm into breeding are the lack of information from characterization and evaluation (quality and performance), the narrow genetic base available, lack of breeding programmes or of specialized staff and the quarantine requirements.

The conditions and requirements that apply to most requests for germplasm include: a SMTA for the two international collections under the International Treaty; a formal approval process from the Research Institutes that have the official mandate from governments requiring the establishment of official links between the requesting institutes; import permits from the recipient country before sending out materials, and sanitary certificates.

2.7 Partnerships and networking

A wide range of partners have expressed their support for the development the Global Strategy for the Conservation and Use of Cacao Genetic Resources. These include national and international cacao research organizations and other institutions which are directly involved in conserving cacao diversity and/or involved in cacao breeding programmes together with many other public and private sector organizations which appreciate the role cacao genetic resources has in ensuring the sustainability of the cocoa economy.

The cacao genetic resources scientific community is currently collaborating through a number of networks, projects and international legal and technical frameworks. CacaoNet is linking all of the key partners in the Global Strategy including working closely with INGENIC. These initiatives are funded and/or facilitated thanks to support from a range of public and private sources.

The key research institutes directly involved in the conservation and use of cacao genetic diversity maintaining *ex situ* collections are listed in the box below, further described in Section 2.3 and the contact details can be found in Annex 3.

• **Benin**	- Centre de Recherches Agricoles Sud Bénin (CRA-SB)
• **Brazil**	- Comissão Executiva do Plano da Lavoura Cacaueira/Centro de Pesquisas do Cacau (CEPEC-CEPLAC)
	- Comissão Executiva do Plano da Lavoura Cacaueira – Ceplac, Superintendência de Desenvolvimento Região Cacaueira no Estado do Pará – Suepa (CEPLAC/SUEPA)
	- Comissão Executiva do Plano da Lavoura Cacaueira – Ceplac. Superintendência de Desenvolvimento da Região Cacaueira no Estado de Rondônia – Suero (CEPLAC/SUERO)
	- Instituto Agronômico de Campinas (ICA)
• **Colombia**	- Corporación Colombiana de Investigación Agropecuaria
• **Costa Rica**	- Centro Agronómico Tropical de Investigación y Enseñanza (CATIE)
• **Côte d'Ivoire**	- Centre national de recherche agronomique (CNRA)
• **Cuba**	- Estación de Investigaciones de Cacao. Estación Central de Investigaciones de Café y Cacao - EIC-ECICC
• **Dominican Republic**	- Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF)
• **Ecuador**	- Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP)

• **France**	- Centre de coopération internationale en recherche agronomique pour le développement (CIRAD)
• **French Guiana**	- Centre de coopération internationale en recherche agronomique pour le dévelop-pement (CIRAD)
• **Ghana**	- Cocoa Research Institute of Ghana (CRIG)
• **Guyana**	- Mabaruma/Hosororo Organic Cocoa Growers Association (MHOCGA)
• **Honduras**	- Fundación Hondureña de Investigación Agrícola (FHIA)
• **India**	- Central Plantation Crops Research Institute (CPCRI)
• **Indonesia**	- Bah Lias Research Station, Sumatra
	- Indonesian Coffee and Cocoa Research Institute (ICCRI)
• **Malaysia**	- Malaysian Cocoa Board (MCB)
• **Nicaragua**	- Laboratorio de BIOciencia, UNAN-Managua
• **Nigeria**	- Cocoa Research Institute of Nigeria (CRIN)
• **Papua New Guinea**	- Cocoa and Coconut Institute (CCI)
• **Peru**	- Central Piurana de Cafetaleros (CEPICAFE)
	- Instituto de Cultivos Tropicales (ICT)
	- Universidad Nacional Agraria de la Selva (UNAS)
	- Universidad Nacional de San Antonio Abad del Cuzco (UNSAAC)
• **Thailand**	- Chumphon Horticultural Research Centre (CHRC)
• **Togo**	- Centre de Recherche Agronomique de la zone Forestière (CRAF)
• **Trinidad and Tobago**	- Cocoa Research Unit of the University of the West Indies (CRU/UWI)
• **United Kingdom**	- International Cocoa Quarantine Centre, University of Reading (ICQC,R)
• **USA**	- United States Department of Agriculture, Agricultural Research Service, Tropical Agriculture Research Station (USDA/ARS)
• **Venezuela**	-Instituto Nacional de Investigaciones Agrícolas (INIA)

These institutes, particularly those holding germplasm in the public domain, together with other organizations, institutions and networks involved in cacao genetic resources in recent years are likely to be involved in the implementation of the Global Strategy. Some of the principal partners are listed below (in alphabetical order) and described in more detail in Annex 5.

Principal organizations, institutions and networks involved in cacao genetic resources in recent years

- Bioversity International
- Centre de coopération internationale en recherche agronomique pour le développement - CIRAD
- Centre for Agriculture and Biosciences Intenrational - CABI
- Centro Agronómico Tropical de Investigación y Enseñanza - CATIE
- Cocoa Producers Alliance - COPAL
- Cocoa Research Association Ltd. - CRA Ltd.
- Cocoa Research (UK) Ltd. - CR(UK) Ltd.
- Cocoa Research Unit of the University of the West Indies - CRU/UWI
- Common Fund for Commodities – CFC
- European Industry Cocoa Research Outreach Group (including the Association of the Chocolate, Biscuits and Confectionery Industries of Europe (CAOBISCO), the European Cocoa Association (ECA) and the Federation of Cocoa Commerce Limited (FCC)
- Global Cacao Genetic Resources Network - CacaoNet
- Global Crop Diversity Trust
- Government of the Netherlands
- International Cocoa Organization - ICCO
- International Cocoa Quarantine Centre - ICQC,R
- International Group for Genetic Improvement of Cocoa – INGENIC
- International Institute for Tropical Agriculture - IITA
- International Treaty on Plant Genetic Resources for Food and Agriculture – ITPGRFA
- Kraft Foods
- Mars Incorporated
- Nestlé
- United States Department of Agriculture - USDA
- University of Reading, UK
- World Agroforestry Centre - ICRAF
- World Cocoa Foundation - WCF

2.8 Constraints affecting the current global system

The key constraints addressed by the Global Strategy are summarised hereunder:

1. Funding for the conservation and sustainable use of cacao genetic resources are well below adequate levels. As a consequence, many collections are conserved in sub-optimal standards and their safeguard is threatened. This seriously impedes on the efficient use of available germplasm.
2. The lack of sufficient expertise and trained staff for the conservation of collections and the use in breeding is recognized.
3. Unnecessary duplication and high frequency of misidentified accessions in collections not only hinders the efficient conservation but also hampers the effectiveness of germplasm evaluation and use. Comprehensive assessment of individual accession identity and phylogenetic relationship amongst accessions is therefore a high priority task.
4. Evaluation of germplasm for economically important traits has only been partially achieved, which is a limiting factor in the uptake of accessions in breeding programmes. Lack of reliable evaluation methods in collections also plays a role, especially so for yield and pest and disease resistance, as well as inadequate documentation of the evaluation results.
5. There is a lack of sufficient variation for important selection traits in existing collections or in some cases, lack of evaluation for those traits.
6. The existing international databases need continued support to improve accessibility and interpretation of the information available. Efforts to install and/or improve local information management systems are needed in some genebanks to facilitate accession management and data-sharing.
7. There are insufficient, inoperative or inadequately managed seed gardens to reproduce selected hybrid varieties in sufficient quantities to satisfy farmer requirements in many areas.
8. The substitution of local varieties (landraces) by clonal varieties in the field can result in irreversible loss of the genetic diversity if not safeguarded in *ex situ* collections. This consequently increases the vulnerability of cacao to sudden changes in climate, and to infection/infestation by new pests and diseases.
9. National laws restricting access to and use of plant genetic resources have emerged in many countries. The introduction of intellectual property rights (IPRs) for new varieties and their genetic components in developed countries has been followed by application of national sovereignty and restrictions on access to these resources in developing countries.
10. The lack of a long-term global strategy and insufficient regional and international collaboration is reducing the capacity of the global system for the conservation and use of cacao germplasm

2.9 Recommendations for the Global Strategy

The following are recommendations to address the major constraints to the long-term conservation and use of cacao genetic diversity at the global level:

1. Secure the conservation of existing *ex situ* cacao genetic resources held in the public domain and their distribution

The Global Strategy provides a clear framework for public and private sector investment in securing the availability of cacao diversity in perpetuity in the most cost-effective manner. It should be an important guiding document for donors, identifying funding priorities.

A stable and long-term source of funding for the major cacao collections is important for their long-term sustainability which must be addressed with urgency. The development of an endowment fund, together with the Global Crop Diversity Trust, is the first priority to guarantee the effective conservation and availability of the basis of cocoa production to those who wish to use it. The endowment will ensure that the conservation of this most vital resource is placed forever on a firm foundation.

2. Development of a Global Strategic Cacao Collection

Ensuring that the entire cacao genepool is conserved *ex situ*, complementing *in situ* conservation, facilitating its access and serving as a safeguard, through the development of a Global Strategic Cacao Collection (GSCC), and its safety-duplication, is a priority and will allow greater focus and cost-effectiveness. With respect to safety duplication, research is needed in cryopreservation to overcome the genotype-dependent response of cacao to somatic embryogenesis and regeneration as a step towards greater cost-effectiveness.

A comprehensive assessment of individual tree identity and understanding the phylogenetic relationship between accessions are of high priority to reduce both levels of misidentification within collections and the redundancy, thereby contributing to the effectiveness of germplasm evaluation and use. With the cost of DNA fingerprinting decreasing with time, verification of accessions at the individual tree level has become feasible.

Since information on accessions is likely to continuously improve over time, the GSCC should be a dynamic evolving collection, to which individuals may be added or, if really necessary, deleted from time to time.

In order to provide exact costing figures, a detailed and comparable costing study of CATIE and CRU/UWI cacao genebank operations and an analysis of duplication should be carried out, using the tool developed by the CGIAR, as well as an assessment of the diversity currently conserved in all collections.

3. *In situ* and on-farm conservation

A greater effort to understand and strategically conserve the diversity *in situ* is required. The establishment of protected areas for *in situ* conservation would benefit all countries, and there should therefore be international participation in this effort.

It is also critical to understand the socio-economic determinants that influence farmers' decisions about the conservation and use of particular varieties in their community. On-farm conservation can be strengthened through activities such as participatory variety selection, cacao breeding and farmer field schools.

Mechanisms for identifying and communicating key threats to crop security/food security, and negative trends crop in genetic vulnerability and genetic erosion (also referred to as "early warning systems") should be developed at national and international level so as to draw attention to immediate threats to *in situ* conservation of wild germplasm and traditional varieties.

4. Genetic diversity gap filling in *ex situ* collections and collecting

Early systematic collecting of the cacao genetic diversity that remains to be captured and its conservation *ex situ*, complementary to *in situ* conservation efforts, is extremely important in view of the rapid rate of destruction of native Amazonian forests. As new technologies are developed, related species and genera of cacao could become important sources of genes for cacao improvement.

The collecting and conservation of the secondary and tertiary gene pool of cacao is proposed based on an analysis of the diversity currently maintained in *ex situ* collections.

There is a need for priority-setting and identification of adequate funding for carrying out collecting trips and for subsequent establishment of the collected materials in *ex situ* collections (in national as well as international collections). The successful establishment of such material in an international collection will require the willing cooperation of the host country holding this wild material. Experience suggests that release of such genetic resources by host countries is not always easily achieved.

5. Strengthening the use of the cacao genetic resources by providing support to breeders and key users through improved characterization, evaluation within collections and supporting population enhancement programmes

The benefits of conserving and utilizing the cacao genetic diversity will only be realized if this diversity is of interest and is made available to researchers engaged in breeding programmes. Funding to support characterization and evaluation of accessions as well as to support the systematic documentation and dissemination of the information is imperative to ensure efficient genebank management and use of genetic resources by breeders. This should include the digitisation and dissemination of important historical data.

Cacao breeders and germplasm curators should take full advantage of the new genomics tools which enable the generation of great amounts of information, to fully utilize and exploit genetic diversity. Proper statistical tools (e.g. spatial analysis, adjustments by common effects) should be used on germplasm data, aiming to improve the quality and coverage of the information provided to breeders.

Pre-breeding activities should continue to be supported in selected genebanks so that material in which genes from different sources have been incorporated, can be made widely available to accelerate progress in breeding efforts.

Research on overcoming genotype-dependant rooting responses, as well as training efforts aimed at transferring propagation technologies to other genebanks is necessary.

6. Improved documentation and sharing of information on germplasm

Access to cacao germplasm and information on key traits of interest to breeders is an essential condition for plant breeding research and agricultural development.

The existing international databases need continued support to improve accessibility and interpretation of the information available. Efforts to install and/or improve local information management systems are needed in most genebanks to facilitate accession management and data-sharing.

Any local information management system will require a minimum level of hardware (computers and networking) and general skills in information technology. There may also be a need for additional training on data collecting and input, particularly where standard descriptors are used.

7. Strengthening the distribution mechanism and safe movement of germplasm

The accessions within the GSCC should be prioritized for distribution to other international, regional or national genebanks as well as to breeders, via intermediate quarantine.

Several genebanks reported that pests/diseases were limiting/preventing them from distributing germplasm. It is essential therefore that all those involved in handling cacao genetic resources have access to information highlighting the risks associated with each particular pest or disease and recommendations on appropriate quarantine measures. Germplasm should be obtained from the safest source possible, e.g. from a pathogen–tested intermediate quarantine collection. Region to region transfer of budwood should take place via a quarantine centre. International standards for phytosanitary measures as published by the Secretariat of the International Plant Protection Convention (IPPC) should be followed.

Securing funding to intermediate quarantine centres is a priority to ensure the distribution of germplasm. The use of Material Transfer Agreements (MTAs) between countries exchanging germplasm via intermediate quarantine should be enforced to ensure that the linkage between the genebank and the receiving country is maintained as well as minimising the impact of misidentifications.

8. Strengthening the networking and partnerships for global collaboration

Training is needed to allow genebank curators to adopt new propagation methods and conservation technologies. The capacity of national partners needs to be built to strengthen the evaluation of interesting materials and the use in breeding programmes. Considerable resources are being invested by the private and public sectors but the cost-effectiveness of these efforts could be greatly enhanced through clearer policies and strengthened global coordination.

A more efficient and effective global conservation and use system should be based on better planning, coordination and cooperation, to reduce costs and ensure that conservation and management of crop diversity is on a scientifically sound and financially sustainable foundation.

Most nations and regions involved in the improvement and production of cacao are highly dependent on genes and varieties developed and conserved in other countries or regions. The efforts needed to secure this material and increase the access to and their use in breeding programmes can therefore only be carried out through international collaboration.

3. Where we need to be to secure diversity and increase use

Based on the constraints affecting the current systems and the general recommendations made by the cacao genetic resources community, the future direction of the Global Strategy has the following eight strategic components, also illustrated in Figure 5 hereafter:

1. Securing existing *ex situ* cacao genetic resources, particularly those held in the public domain, and their distribution.
2. Developing a Global Strategic Cacao Collection (GSCC).
3. Genetic diversity gap filling in *ex situ* collections and collecting.
4. Ensuring the *in situ* and on-farm conservation of important genetic diversity.
5. Strengthening the distribution mechanism and safe movement of germplasm.
6. Strengthening the use of the cacao genetic resources by providing support to breeders and key users through improved characterization, evaluation within collections and supporting population enhancement programmes.
7. Improving documentation and sharing of information on germplasm.
8. Strengthening the networking and partnerships for global collaboration.

Theobroma speciosum (Ph. Lachenaud, CIRAD).

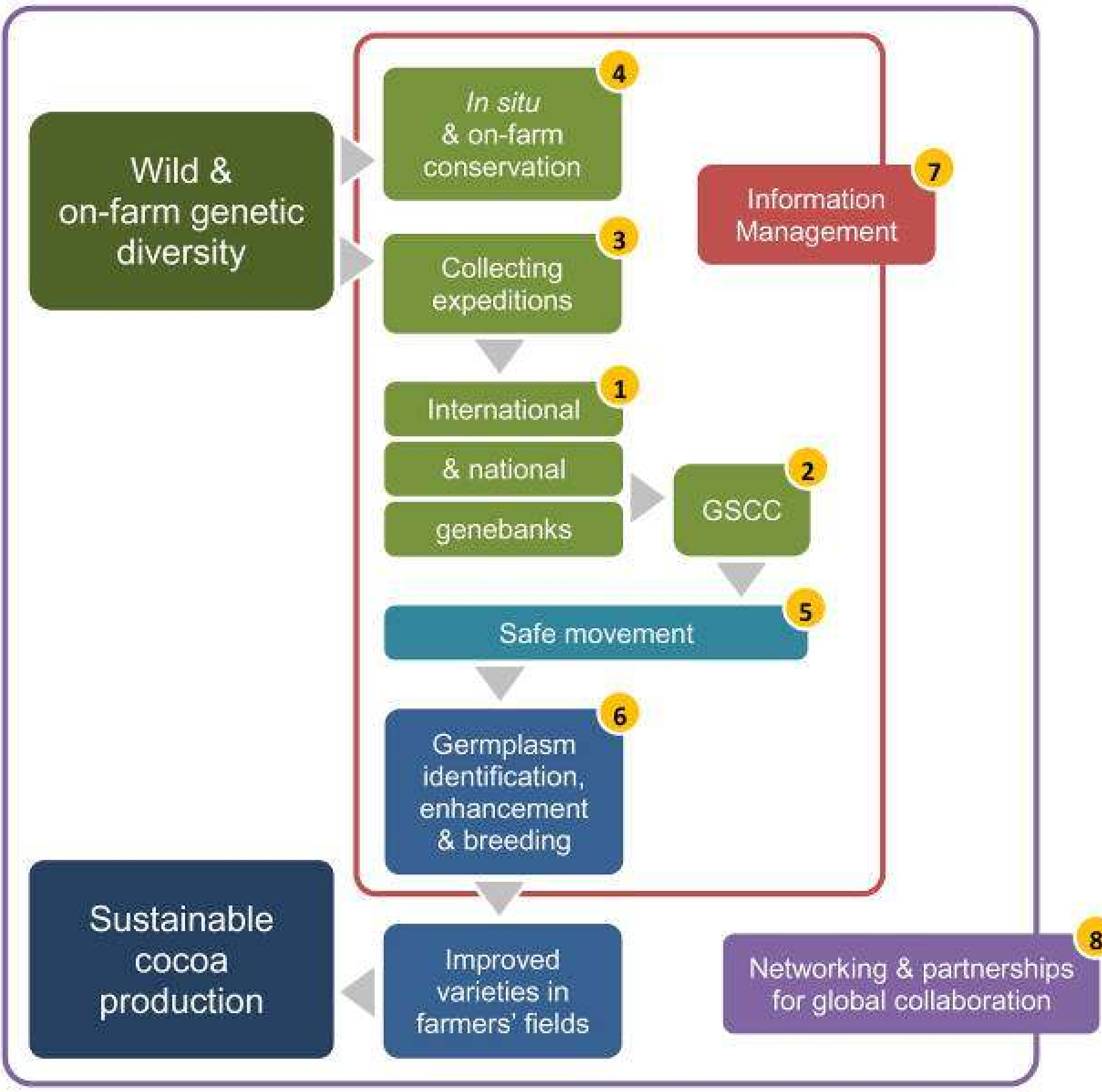


Figure 5. The main strategic components from genetic diversity to sustainable cocoa production (Credit: C. Turnbull, Reading University).

3.1 Securing existing *ex situ* cacao genetic resources and their distribution

The immediate priority of the Global Strategy is to secure the conservation and accessibility to all users of existing and valuable genetic diversity currently in *ex situ* collections, particularly those held in the public domain. This diversity is critical to ensure the future of the world cocoa production to generate planting materials which can improve productivity today and those of the future which might require very different characteristics in the face of new pest and disease challenges, climate change and different agronomic conditions, and changing consumer preferences.

The Global Strategy provides a clear framework for public and private sector investment in securing the availability of cacao diversity in perpetuity in the most cost-effective manner.

The funding of conservation and use activities of cacao genetic resources is currently born by the many national research institutes with the help of industry and international organizations and is below optimal levels. Even the funding to the two international collections at CATIE and CRU/UWI and the ICQC,R is only a three-year planning basis, is not guaranteed and therefore their sustainability is not secured over the long term. Many national collections are struggling to keep their material alive.

The Global Strategy calls, as a first priority, for the development of an endowment fund (or similar sustainable funding mechanism) dedicated to the conservation and use of cacao genetic resources in the same way that the Global Crop Diversity Trust[5] has been established to do so for the food security crops included in the International Treaty. It is proposed that an endowment fund for cacao would model its funding principles and criteria to those developed by the Trust, fully in line with the objectives of this Global Strategy. Its highest priority would be to secure collections of distinct and valuable genetic resources in the public domain, by:

- securing the conservation and availability (including its safety-duplication),
- promoting participation of all partners through support for documentation systems, characterization and evaluation, collecting to fill gaps and promoting access to and use of materials, and
- increasing efficiency and effectiveness to reduce costs and increase sustainability.

The support would aim to increase and improve the capacity of all to participate in, contribute to and benefit from the global system for long-term conservation and use of cacao genetic resources. The specific activities to be carried out are detailed in Sections 3.2 to 3.8 below and proposed workplans and budgets in Sections 4.1 to 4.8.

It is acknowledged that building such an endowment fund and securing funding for all the components of the Global Strategy may take some time; the highest priority will be to secure the conservation of the genetic diversity currently held in the public domain in *ex situ* collections and facilitate its distribution via intermediate quarantine.

[5] The Global Crop Diversity Trust was founded by the United Nations Food and Agriculture Organization (FAO) and Bioversity International, acting on behalf of the foremost international research organizations in this field (CGIAR).

3.2 Developing the Global Strategic Cacao Collection (GSCC)

Only the two international collections at CATIE and CRU/UWI have placed their cacao germplasm under the auspices of the Governing Body of the ITPGRFA, with the commitment to safely conserve for the long term according to international standards and make the materials readily available to any plant breeding programmes and other *bona fide* users. However, some national collections can also be considered to bewithin the public domain, such as the collections at CIRAD and USDA. In addition, the ICQC,R holds cacao accessions available in the public domain and is the only international quarantine centre for the safe movement of cacao genetic resources throughout the world.

CATIE International collection, Costa Rica (W. Phillips, CATIE).

The remaining collections are considered to be a national asset and are generally not publicly available outside of the country holding the collection. In many Latin American countries possessing primary sources of cacao genetic diversity, policies restrict opportunities for newly collected materials to be put into the public domain. Unique and valuable material is conserved in these national collections and thus, collaboration is needed to secure this material and increase the access to and their use in breeding programmes.

CRU/UWI International collection, Trinidad and Tobago (M. Gilmour, Mars Inc.).

But most importantly, no country is self-sufficient when it comes to the range of genetic diversity needed to develop improved materials. This diversity is maintained by several research institutes but only a part of that diversity is in the public domain.

CacaoNet is working towards the establishment of a Global Strategic Cacao Collection (GSCC) as a virtual collection consisting of materials that have been identified as unique and interesting. Each of the participating institutes will agree to conserve these accessions according to agreed practices and standards and make them readily available to any *bona fide* user. The objective of the GSCC is therefore to ensure the cost-effective and efficient long-term *ex situ* conservation of the entire *Theobroma* genepool and its accessibility to all current and future users. The formation of the GSCC will result from a coordinated effort of characterization and rationalization of available cacao genetic resources. The materials in the CATIE and CRU/UWI collections will form the backbone of this GSCC complemented with priority accessions from national collections.

Agreed criteria such as genetic diversity, in the form of allelic richness and the uniqueness of each genotype, in combination with measures of agronomic value will be used to identify priority accessions. Once the main part of the GSCC is formed, adding new diversity will be based on ensuring the genotype significantly increases the genetic diversity of the GSCC and/or this genotype has specific agronomic, quality or physiological traits that are of interest to users.

A first set of accessions will be selected on the basis of capturing the greatest possible range of allelic richness. These accessions would preferably be in the public domain but it is acknowledged that currently some may be maintained in collections not yet in the public domain. The Global Strategy aims to ensure that the institutes managing these accessions would conserve them for the long-term, evaluate them and take the necessary steps to make them publically available. Two agreed core selection methods are employed. Both use grouping and selection of an optimum set of accessions followed by a further iteration designed to reduce the redundancy of the core selection (van Raamsdonk & Wijnker, 2000; van Treuren et al., 2008 & 2009). The method is illustrated by way of reference to a large public dataset of simple sequence repeat (SSR) information (microsatellite markers). The detail of the method is included in Annex 6 (Description of the agreed methodology to select accessions based on allelic diversity). It is now possible to characterize gene sequence and nucleotide polymorphism at large numbers of loci. Following a comprehensive literature review to identify those traits known to be under well-defined allelic control, the part of the GSCC based on allelic diversity should be subject to a detailed analysis of gene coding and regulatory regions, to catalogue the variation present at those loci in order to encourage the exploitation of this resource. However, the method is not limited to the analysis of molecular genetics data but can combine both discrete categorical and continuous variable data on botanical or agronomic traits. The GSCC currently identifies 261 accessions that represent the maximum allelic richness observed across ten population groups, capturing the majority of the known genetic and geographic diversity held within *ex situ* collections worldwide. The proposed accessions are listed in Annex 7 (Membership of accession for the GSCC based on allelic diversity). Also, considering that some of these collections have accumulated a large amount of data (e.g. 70% of CEPEC`s collection was well evaluated for several years for resistance to witches' broom disease and many yield components) it is an opportunity to find associations between markers and important traits.

A further set of accessions will be selected on the basis of key traits of interest to users such as yield, flavour characteristics and disease resistance for which agreed criteria will be developed. Criteria for selection of genotypes may include in addition to the number of desirable traits present, the genetic diversity amongst the selected types as determined through DNA fingerprints. This part of the GSCC will complement the part selected on allelic diversity and be a dynamic and geographically dispersed collection composed primarily of wild species and populations, landraces, enhanced populations for which characterization and evaluation data is available and used to broaden the basis on which the selection is made. This material will be in the public domain and accessible in the collections at CRU/UWI and CATIE for which considerable characterization and evaluation data are already available. Additional materials from national collections will become part of the GSCC if the governments concerned are willing to place them in the public domain. A first step will be the development of a list of priority genotypes identified with known agronomic/economic value. This set would be dynamic in nature, adapting to current and potential future needs.

As far as possible, genetically similar genotypes should be avoided to reduce redundancy. There may not be sufficient information on all publically available accessions to allow the identification of priority materials for the GSCC, so a comprehensive assessment of individual identity, verification of a given accession to be true-to-type and population structure, are high priority tasks. The assessment of the complementarities and duplications between the two international collections should be a priority for the establishment of the GSCC.

Since information on accessions is likely to continuously improve over time, the GSCC should be a dynamic evolving collection, to which individuals may be added or, if really necessary, deleted from time to time.

New technologies for cacao, such as *in vitro* culture and cryopreservation, could be used to complement field genebanks to ensure the duplication of the GSCC providing they can be shown to be cost-effective. Cryopreservation is a technology that is far enough advanced to be applied to a large number of genotypes, despite some genotype-dependency for somatic embryogenesis. However, the method is expensive so the application of this method might initially focus on the safety duplication of priority accessions. CacaoNet would lead the process of consultation on safety-duplication and the use of cryopreservation with all its members and develop agreements on behalf of its members.

The accessions within the GSCC should be prioritized for distribution to other international, regional or national genebanks as well as to breeders, via intermediate quarantine. The collection managers and breeders around the world will be responsible for comprehensive characterization, evaluation and further researching of the GSCC collection. All related information should be made available to all users through GSCC information portal to allow the selection of materials for inclusion in the GSCC (see details in Section 3.7).

The specific criteria and boundary for each set of accessions would be agreed through a consultation process coordinated by CacaoNet. This assessment would be part of a rationalization plan, with clear objectives, that would take place over time as knowledge becomes available. CacaoNet members would be responsible for the composition of the GSCC as well as for recommending and where possible supporting priority actions such as detecting mislabelling, evaluation, characterization, pre-breeding, distribution and use. This would include the participation of collection curators and the breeding community represented by INGENIC.

CacaoNet will also ensure the continuing development of the GSCC in consultation with all its members. Partners will agree on how to share responsibilities for conserving and distributing material from the GSCC. The management responsibility of the identified accessions would reside with the various genebank curators. Long-term funding will be discussed with the Global Crop Diversity Trust, other international donors and with the private sector. CacaoNet expects to continue to facilitate the dialogue between the ITPGRFA and the countries that are maintaining cacao materials targeted by the GSCC, in order to encourage countries to follow the example of CATIE and CRU/UWI and place selected accessions under the Treaty.

The process of developing the GSCC is represented in Figure 6 (see next page).

3.3 Genetic diversity gap filling in *ex situ* collections and collecting

Theobroma wild species from Ecuador (F. Amores, INIAP).

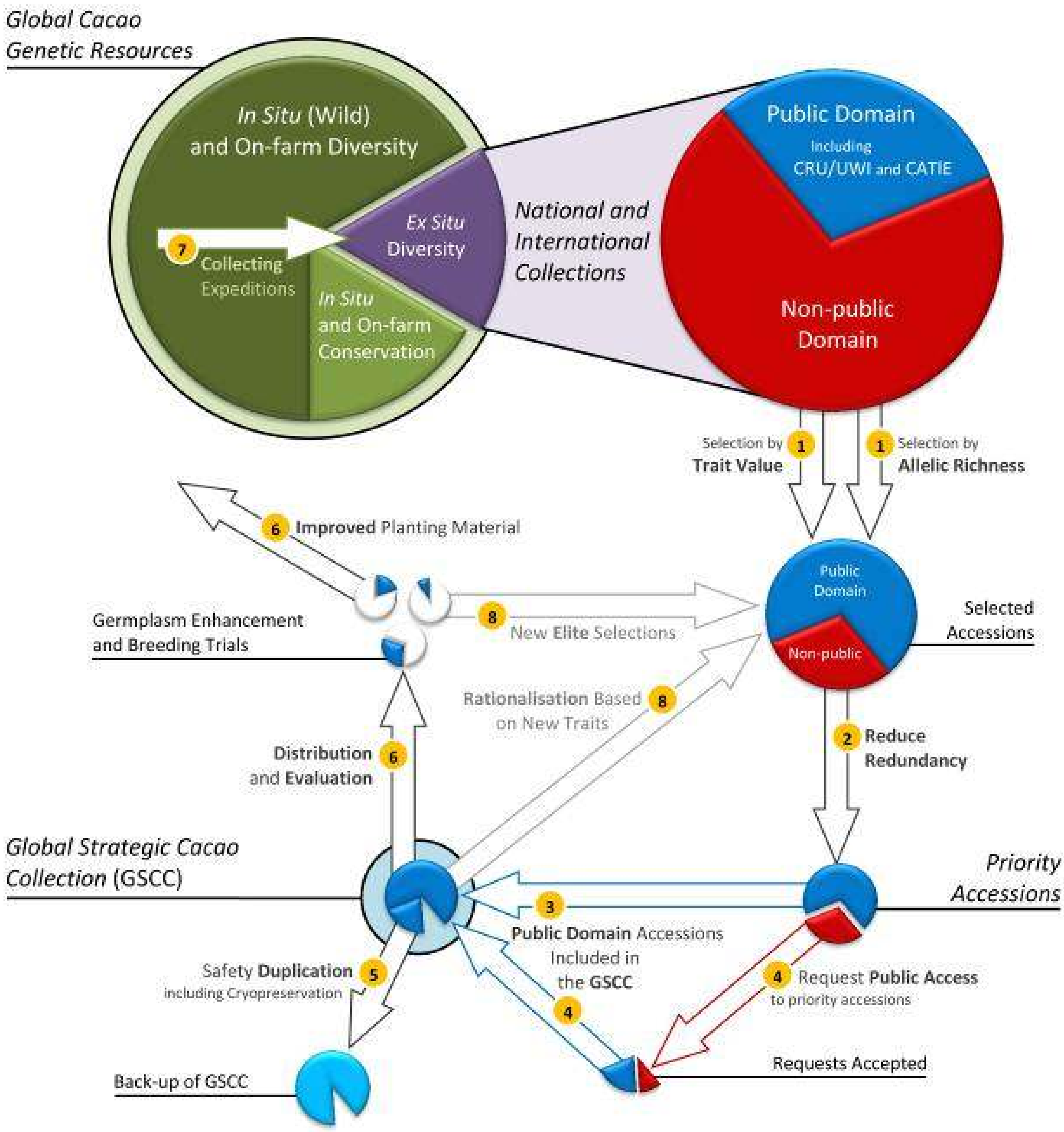
The main criteria for priority setting to carry out new collecting actions are degrees of threat to the natural habitat of cacao and filling gaps in the existing diversity in collections. Another priority is related to opportunities that may arise to collect materials in areas that have not yet been prospected or where the material collected does not fully represent the diversity present. The collection activities are included in Figure 6 above and point 7.

Early warning systems should be developed at national and international level so as to draw attention to immediate threats to *in situ* conservation of wild germplasm or traditional varieties.

Gaps in genetic diversity in *ex situ* collections refer to geographical areas that are under- or not represented in collections and where cacao is expected to occur based on ecological and other factors. Geographic Information System (GIS) will be used to analyze spatial distribution of different cacao populations. Gap analysis should be applied to map the actual distribution, agro-climatic preferences, and potential distribution of cacao. The degree of variability expected to be found in new collecting areas is another important consideration. Information on allelic diversity in the wild cacao populations will be used as an important criterion to guide future collecting missions. Collecting actions also may be directed to areas where higher frequency of desired traits, such as disease resistance, is expected to be found.

Three types of germplasm to be collected should be prioritized:

1. Wild populations of *T. cacao* (spontaneous trees (native) and sub-spontaneous trees (not native).
2. Landraces and traditional varieties (i.e. germplasm with little or even no genetic selection or improvement from farmers). These varieties are generally mass-selected and planted as seeds or seedlings by farmers, but grafting might also be carried out.
3. Wild *Theobroma* spp. or species from other genera related to *T. cacao*.



1. Genetic diversity in combination with measures of agronomic value will be used to identify accessions of interest.
2. A second round of selection aimed at reducing redundancy will generate the list of Priority Accessions.
3. Priority Accessions in the public domain will become part of the GSCC.
4. Public access will be requested for any Priority Accession not already in the public domain so that it can be included in the GSCC.
5. Each GSCC accession will be duplicated in another field collection for safety, and some may also be backed-up through cryopreservation (International quarantine required).
6. Material in the GSCC and all its associated information will be freely available for use in germplasm enhancement and breeding programmes, resulting in improved planting material becoming available to farmers (International and/or regional quarantine required).
7. Future collecting expeditions will target gaps in the GSCC (International and/or regional quarantine required).
8. Rationalization of the GSCC will continue as new material becomes available from collecting expeditions and breeding programmes.

Figure 6. Process for the development of the Global Strategic Cacao Collection (GSCC) (C. Turnbull, Reading Univ.).

The main difference between the wild population and the landraces is that for landraces selection has reduced the allelic diversity and/or modified allele frequency. This of course depends on how long ago the domestication took place.

Safeguarding the spontaneous wild populations or demes (sub-populations) is paramount and urgent in threatened areas because of intense deforestation, such as in: Bolivia (Ríos Madre de Dios, Beni and Mamoré), Brazil (Rondonia, North Mato Grosso, Pará), Peru (Ríos Ucayali, Huallaga, Madre de Dios, Putumayo) and Venezuela (Río Orinoco). In parenthesis are examples of areas with known gaps. A full list should be based on the result of a gap analysis. Collecting trips should be planned in areas not adequately covered so far by collecting actions, such as Guyana (Plateau), Brazil (Amapá, Roraïma), French Guiana, Suriname, Venezuela and Colombia (Amazon region).

Regarding the conservation of landraces, examples are cacao trees with "amelonado" or "calabacillo" type pods in Central America ("Indio", "Matina", Ceylán, etc.), West Indies ("Créole") and northern South America. A large-scale collecting mission and comprehensive study of this material should be undertaken in Honduras, Nicaragua, Lesser Antilles, Orinoco delta, Colombian Pacific coast, etc. Other examples are the landraces domesticated from wild materials in Peru (e.g. Chuncho) and in Bolivia ("Nacional" types).

With few exceptions related species including *Theobroma* spp. as well as *Herrania* species are largely under-represented in existing *ex situ* collections. Although there are important barriers in crossing most related species with *T. cacao*, the use of modern tools (protoplasm fusion, embryo rescue, genetic transformation) may make it possible to exploit these species in the longer term for the improvement of cacao. Some principles should be set out: (1) the collected germplasm will be planted first (in *ex situ* collections) in the country of origin; and (2) collecting trips should be carried out during the fruiting season, even if it coincides with the wet season.

Many previous collecting expeditions, especially those prior to the 1980s, have focused on collecting germplasm from individual trees showing desired agronomic traits such as disease resistance. Usually, such collections were limited to only those few, or even unique individuals showing the desired traits. This approach has thus reduced the number of samples available for analysis from a given location/population in diversity studies.

Therefore, future collecting missions should have the objective to safeguard alleles in populations and sub-populations (demes). To do so, pods should be collected from an appropriate number of trees (ideally 20), randomly chosen in each deme, with priority given to gaining a representation of the existing phenotypic diversity. If pods are unavailable from sufficient trees then leaves should be collected for DNA analysis to assess whether the individuals collected from the population are representative of the wild germplasm present. If trees displaying interesting characters, such as a low incidence of disease, are found, pods and budwood should also be collected. For landraces, it will be necessary to collect also numerous historical data and information from old planters and their families. A standardized collection form should be developed collaboratively.

It must be stressed that an important step will be to obtain the administrative authorization necessary before any collecting trip, due to the Access and Benefit Sharing (ABS) clauses in the Nagoya Protocol (2010). When the permits to collect are obtained from the authority concerned in a given country, the aims and objectives of the project will be explained to the local populations using language that they can understand and the results will be returned to them in a meaningful way. Local farmers associations and non-governmental organizations (NGOs) might be important links in facilitating meaningful communication.

An important constraint is the lack of regular funding for collecting trips. A working group should be set up within CacaoNet that proposes priority collecting activities and tries to identify adequate funding for carrying out collection trips and subsequent activities to establish the collected materials in *ex situ* collections (in national as well as international collections).

3.4 Ensuring the *in situ* and on-farm conservation of important genetic diversity

Relative to *ex situ* conservation, cacao is less studied in terms of *in situ* and on-farm conservation. The latter is influenced by complex social, political and biological factors. There is a threat to the continuity of habitat for *Theobroma* species growing in the wild.

As described in Sections 2.1.1 and 2.2.2, the distribution and diversity of these resources is not well understood and collections are hence limited.A greater effort to understand and strategically conserve this resource *in situ* is required.

Pruning demonstration in Fiji
(R. Markham, ACIAR)

For this reason the collecting and characterizing new genetic resources by host countries is desirable as a safeguard against the resources being lost from the wild, and should be facilitated by CacaoNet if and when possible, notwithstanding that these materials are unlikely to be placed in the public domain in the foreseeable future. Strategic alliances should be developed and synergies need to be harnessed from different conservation initiatives in terms of *in situ* conservation of uncultivated cacao populations. These include various initiatives such as national forest reserves, wildlife refuges, and private reserves, all of which can help preserve natural plant communities. The Global Strategy should foster partnership between government agencies, scientific research institutions, NGOs and farmer communities and possibly the private sector for *in situ* conservation of uncultivated populations.

Regarding on-farm conservation, farmers make the ultimate decisions about the conservation and use of particular varieties in their community. It is therefore critical to understand the socio-economic determinants that influence their decisions. The traditional cacao varieties often have lower yield but some of these have acquired a reputation for quality and are increasingly coveted by external gourmet specialty markets. In some cases these landraces can also be important sources of resistance to pests and diseases. For example the Bahian Amelonado is more resistant than average to *Ceratocystis*. In the Brazilian Amazon area there are landraces that have been planted for years (and probably selected for resistance) which tend to be more resistant to witches' broom disease.

Production and marketing of differentiated high-value cocoa provides an opportunity for conservation through use of threatened cacao diversity. Higher farm-gate revenues from the premium market, which has been increasing at an annual rate of 16% in the last five years, may provide incentives for demand-driven on-farm conservation. On-farm conservation can be strengthened through activities in the farming community, such as participatory variety selection, cacao breeding and farmer field schools.

Therefore, a major *in situ* and on-farm component of the Global Strategy should focus on the generation and management of pertinent socio-economic and biological information. The other principal elements have been identified as:

1. continued use of landraces and traditional varieties for cocoa production,
2. habitat management, and
3. alliances and partnership in integrated regional development.

3.5 Strengthening the distribution mechanism and safe movement of germplasm

It is important to clarify and influence the legal situation regarding access to cacao genetic resources in individual countries, by improving awareness of existing conservation and research/breeding activities in the country and by sharing information regarding international (and sometimes national) policies and legislation regarding access and benefit-sharing. This can facilitate the involvement of decision-makers in formalizing arrangements for the exchange of cacao genetic resources as well as improve their political understanding of the role of conservation and use of cacao genetic resources towards supporting the development of a sustainable (institutional) cacao industry in the country.

CacaoNet will continue to collaborate with national collections, FAO, the Global Crop Diversity Trust and the International Treaty to promote the placing of cacao germplasm collections in the public domain through designation under the Treaty, as was achieved with CATIE and CRU/UWI. Once cacao accessions have been given a public domain status, they can become freely available to bona fide users and exchanged legally, transparently and fairly, through the use of a MTA.

In recognition of the difficulty that some countries face in placing cacao genetic resources in the global public domain, it was suggested that a more pragmatic approach could be adopted to allow the exchange of accessions which were already

International Cacao Quarantine Center, Reading, UK (A. Daymond, Univ. Reading).

in international collections but which have been lost. A few examples were given of accessions which have been lost from the CRU/UWI collection, i.e. ICS 55 and NA 33 and the hope was expressed that countries where these clones still exist would not have any problem in exchanging or returning these. Another priority would be the exchange of cacao germplasm that is genetically distinct or perhaps has disease and insect resistance, not including, for the time being germplasm noted for specific qualities, often flavour attributes, which are characteristic of a country's production. Such an arrangement would eliminate the fear that through the exchange of germplasm a given country might well strengthen the competitive edge of other countries and thus, undermine its own position.

The updated 2010 Safe Movement Guidelines are initially being published online as a Bioversity/CacaoNet publi-cation. It is intended that the guidelines would be sent out on a CD to relevant institutes. Translation into French and Spanish is being considered. Furthermore, recipients will be encouraged to translate the document, or sections of it, into additional local languages to improve adoption of the guidelines.

CacaoNet will engage with the International Plant Protection Convention (IPPC) and its Regional Plant Protection Organizations to ensure that these guidelines are widely available to those responsible for the phytosanitary systems in cocoa producing countries. The IPPC works with Convention contracting parties, to develop phytosanitary measures that underpin the parties' ability to manage pest risks and the environmental, economic and social impacts of plant pests. The IPPC is governed by the Commission on Phytosanitary Measures (CPM), which meets annually to review the state of plant protection, identifies action to control the spread of pests into new areas, develops and adopts international standards and establishes procedures for the sharing of phytosanitary information. The IPPC works with Regional Plant Protection Organizations and international organizations to build phytosanitary capacity, to identify and address risks that cross national borders.

The CacaoNet Working Group on Safe Movement should continue to meet in order to update the guidelines as new information becomes available on cacao pests and diseases and also consider new technologies as they become available. It should continue to consider the most effective means of raising awareness and communicating the importance of safe germplasm movement to the cacao community, including on a regional basis, since without this understanding, there is the danger that illicit movement of cacao plant material will spread pests and diseases, thus threatening the sustainability of future cacao production. The guidelines should be formally reviewed every two years, although should new information become available in the meantime, e.g. on the spread of a particular pest, then the guidelines will be updated accordingly.

CacaoNet should promote the development of regional quarantine centres to complement the role of securing international movements through the ICQC,R. Currently material appears to be moving directly within regions incurring phytosanitary risks. A regional quarantine approach can facilitate the exchange of germplasm between countries where the same cocoa pest and diseases are endemic.

The quarantine activities are illustrated in Figure 6 above by points 5 and 6.

3.6 Strengthening the use of cacao genetic resources

Drying of cocoa beans, Ecuador
(A. Eskes, CIRAD/Bioversity

The use of accessions in the GSCC should start with the evaluation for economically important traits. The main traits to be assessed are yield determinants, disease resistances, yield components, precocity and tree size (quality and vigour). Although increased yield potential is the main aim, yield potential can only be reliably estimated in collections with uniform planting conditions or by the use of appropriate statistical tools. Drought tolerance and establishment ability in cacao have also become important traits due to the growing concerns about climate change, notably with the dry seasons getting longer, harsher and less predictable in some regions of West Africa. Further prioritization on specific traits will be required under the coordination of CacaoNet. Once evaluated, selected accessions that possess the requested traits can be sent to intermediate quarantine for distribution to countries that are interested in acquiring germplasm for use in breeding programmes. The evaluation activities are illustrated in Figure 6 above by point 6.

To facilitate the selection of new accessions to be introduced by user countries, a list of the main traits of accessions held in the ICQC,R should be made available to the user countries. Such information is accessible in the ICGD which also provides access to the new Genetic Resource Evaluation and Selection Tool (GREST), developed to help breeders prioritize their germplasm requests and choose material from their local genebank for inclusion in their breeding trials by ranking accessions according to the user's choice of characteristics using data available in the ICGD. Information on GSCC accessions not at the ICQC,R will be made available via the GSCC information portal (see section 3.7 below).

The introduction of new accessions from international collections can often be driven by a specific goal, e.g. black pod resistant accessions in countries that suffer significant losses due to this disease. Another objective can be to introduce clones with resistance to diseases that are not yet present in the country, so that resistance can be incorporated into breeding lines as a safeguard in case of the accidental entry of the disease. A typical case is the need for introduction into Africa and into Asia of genotypes with resistance to the South and Central American witches' broom and frosty pod diseases. Furthermore, countries may wish to introduce germplasm from a particular genetic group that is under-represented in their national germplasm collections, aiming at broadening the genetic base of these collections. A key step in the use of primary accessions is the germplasm enhancement or pre-breeding programme implemented by CRU/UWI. The first cycle for black pod resistance is nearly completed, but the witches' broom resistance enhancement programme is less advanced. A priority is therefore the finalization of both the black pod and witches' broom enhancement programmes in Trinidad, including continuing to make available the best selections through the ICQC,R.

Cacao breeders and germplasm curators can now take advantage of the new tools of molecular biology and genomics to fully utilize the potential of cacao germplasm. The genomics and information revolution has enabled the generation of great amounts of information about the *T. cacao* species. The availability of full sequence information of the cacao genome (Criollo and Matina 1-6) represented a critically important step toward the development of new molecular tools for unlocking genetic diversity in cacao germplasm, with a higher precision than ever before. There is an urgent need to agree on the composition of an international SNP set for genetic fingerprinting in the same way that a common set of SSR markers has been internationally agreed upon to facilitate comparison of results from different laboratories.

Utilization of collections and the associated science can contribute to cocoa agriculture through delivery of improved varieties only through strong national breeding programmes. As we have seen, the system for practical cocoa breeding is weak. Such programmes are under-resourced in most countries. Cacao breeding itself is of no use if it is not followed by efficient programmes to multiply selected varieties, either in seed gardens (hybrid varieties) or in budwood gardens (clonal varieties) at the national level. To secure the use of cocoa genetic resources, systems for proliferating and distributing new varieties are of high priority and capacity building in this area is critically important.

3.7 Improving documentation and sharing of information

A simple yet robust information management system, that combines comprehensive and accurate information on the origins, conservation locations, availability and characteristics of individual accessions, will be the portal to accessing all relevant information and be a key component in the establishment, management and use of the Global Strategic Cacao Collection (GSCC).

As part of the GSCC information portal, a central database, CANGIS (CacaoNet Germplasm Information System), will bring together all the genebanks and other service providers that collectively form the GSCC and facilitate their effective management. CANGIS will be a relatively small online database that will maintain specific, high quality data (including passport descriptors and the characters supporting an accession's inclusion in the GSCC) on all the individual accessions that make up the GSCC, and provide a means for users to access this germplasm. This information will be based on individual trees located at specific sites. CANGIS will link to existing international databases, such as ICGD and TropGENE (utilizing standardized variety identification codes), in order to access additional information that is of interest to potential users of the germplasm. This will take the form of either a direct link (taking the user to the other database) or a web service (where information is retrieved from another database, but integrated into the host's output). Users of these international databases will also be able to link back to CANGIS in order to access information on individual accessions in the GSCC and their availability.

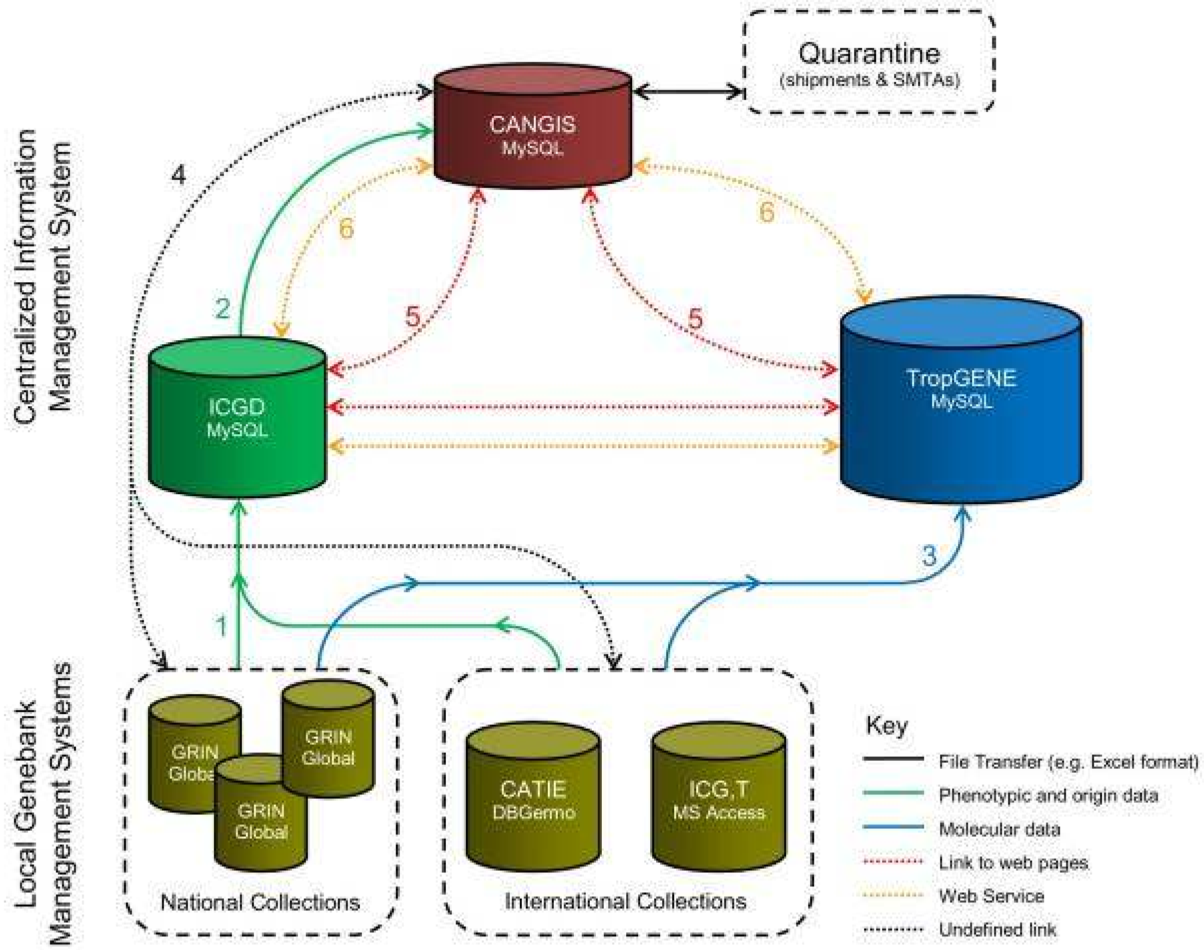
In order to ensure that a minimum standard of record keeping is maintained for the entire 'virtual' GSCC, local germplasm management systems need to be in place at each of the genebanks holding accessions that are part of the GSCC. Some genebanks already have such a system established, or are under development, whilst others will need to install one. These local germplasm management systems must facilitate a good flow of information back to the GSCC information portal to allow effective management of the GSCC as a whole. However, they must also work at the level of the individual genebank, which may hold collections of other crops and be spread over several locations, and not require a significant amount of additional time or computer skills to use. In order to link CANGIS to the accessions maintained at each collaborating genebank, a minimum standard of record keeping is required at the local genebank level. The local genebank documentation system must be able to link passport data, plus any additional characterization or evaluation information, to specific trees in the field and then make this information more widely available.

A prototype version of CANGIS has been developed using information from ICGD on International Clone Trial (ICT) accessions (Eskes and Efron, 2006) held in the international collections at CRU/UWI and CATIE. CANGIS already includes a link to ICGD, taking the user directly to a page of evaluation data for a specific genotype, and more links are being developed.

Movement of material into and out of the 'virtual' GSCC should be monitored, including transfer for safety duplication. This would provide up-to-date information on the management of accessions within the GSCC and how they are being used. The monitoring system would link to the network of local genebank management systems, providing up-to-date information on the location and availability (e.g. quarantine status) of each of the widely distributed accessions in the GSCC. See Figure 7.

A likely future development for the GSCC information portal is the provision of a germplasm ordering system that would allow the user to select the most appropriate germplasm accessions in the collections accessible in the public domain based on passport, characterization and evaluation data. The germplasm ordering system would take account of the guidelines for safe movement of cacao germplasm and link accessions to a MTA. The ordering system would also serve the purpose of tracking movement of germplasm in a similar way that the global information system for the International Treaty does.

Technologies such as GPS and barcoding are not widely used in cacao collections at the current time, but they are becoming less expensive and more widely available, and likely to be increasingly important in managing genetic resources in the future. In some countries like Brazil, this process has already started. Under a new law, all germplasm accessions of all species will have to be geo-referenced (GPS positioned). The use of GPS equipment during collecting missions should also be encouraged.



1 Characterization and evaluation data are sent to ICGD (includes non-CacaoNet accessions and information).

2 Once checked and standardized, information on the Global Strategic Cacao Collection accessions is entered into CANGIS.

3 Molecular data are sent to TropGENE (includes non-CacaoNet accessions and information).

4 A degree of direct networking between Global Strategic Cacao Collection IMS and the local genebank management systems is required for monitoring/tracking accessions in the base and active collections. The form this will take will largely depend on the genebank management systems that are adopted (e.g. GRIN-Global).

5 In order to access additional information available from one of the other databases, the user can be linked directly to the relevant page on the collaborating website (all of the databases use the same variety identification codes).

6 Web services allow an information management system to query distributed databases and integrate the results with its own output, removing the need to physically transfer the user to the other database.

Figure 7. Components of the GSCC information portal (C. Turnbull, Reading University).

The successful integration of a network of local genebank management systems into the GSCC information portal is particularly important due to the widely dispersed nature of the accessions that will make up the "virtual" GSCC. The international collections at CATIE and CRU/UWI already utilize computerized genebank management systems, but many other collections do not yet have such well-developed information management systems in place. As most collections are already aware (CacaoNet surveys 2008-2012), a robust and easy to use local management system would also be of direct benefit to local staff.

Collection curators may be encouraged to adopt the same standardized system, such as GRIN-Global. GRIN-Global is a project whose mission is to create a new, scalable version of the USDA's Germplasm Resources Information Network system (GRIN) suitable for use by any interested genebank in the world. It is being developed in a joint effort with the Global Crop Diversity Trust, Bioversity International, and ARS/USDA. The project's goal is to provide the world's crop genebanks with a powerful, flexible, easy-to-use global plant genetic resource (PGR) information management system. The database and interface(s) will be designed to accommodate both commercial and open-source programming tools, to be database-flexible, and to require no licensing fees for genebank use. However GRIN-GLOBAL may need to be customised for managing cacao germplasm.

During the transition phase of adopting GRIN-Global, Excel templates will be developed to help curators provide standardized information whenever possible, though ICGD would continue to accept data in any format. In addition, since the system records the donor of each accession, it would help identify, trace and restrict the impact of mislabelling events. For this reason, each accession's verification-status would also be indicated.

The main areas of capacity building are associated with the local information management system. If a collection chooses to use GRIN-Global, training and support will be required for staff who will maintain the system. The initial set up of the system will likely require additional training and may best be carried out at a regional or international level, with experts on GRIN-Global carrying out this initial set-up in collaboration with local staff.

Any local information management system will require a minimum level of hardware (computers and networking) and general skills in information technology. There may also be a need for additional training on data collecting and input, particularly where standard descriptors are used.

The CacaoNet website (www.cacaonet.org) will provide a single point of access for all the elements of the GSCC information portal, providing also a basic overview of cacao (including the centre of diversity, the main production areas, spread of pests and diseases, etc.) and explains the importance of cacao globally, highlighting public awareness issues. Information on CacaoNet would also be available, targeted to different user groups (including potential donors, existing partners and the general public).

3.8 Strengthening the networking and partnerships for global collaboration

The global system for conservation and use of cacao genetic resources is based on safeguarding the unique and critical diversity, making it available to breeding programmes and other research institutes via a system for safe movement of germplasm. The system therefore relies on a network of partners including well-functioning and efficiently-managed international and national *ex situ* collections collectively conserving and making available the materials identified for the GSCC.

Through an active participation in CacaoNet, a partner will be able to ensure that the decisions made by the Network are advantageous to their country in managing and using cacao diversity. Strengthened regional cooperation will facilitate the rationalization of existing and future cacao collections, and reduce duplication of efforts.

CacaoNet supports and strengthens the following aspects:

- Long-term effective and cost-efficient conservation of important genetic resources.
- Consolidate and facilitate access to information and knowledge on cacao genetic resources worldwide, on germplasm (characterization and evaluation), on quarantine precautions/ regulations and on molecular genetics data.
- Facilitate access to standardized protocols on characterization, evaluation, information analysis and long-term conservation of germplasm.
- Facilitate access to technologies, procedures and methods to conserve, improve and breed cacao, e.g. molecular genetics tools; cryopreservation; somatic embryogenesis; others.
- Promote and facilitate the distribution of enhanced populations to users, particularly for resistance to witches' broom, black pod and frosty pod diseases from materials in the two international collections at CRU/UWI and CATIE.
- Provide pertinent legal information and advice, particularly on access and benefit-sharing and assist partners in implementing regulations.
- Represent the many beneficiaries of the Global Strategy through one voice and partnership to secure long-term funding of the key strategic elements and research activities.

The national cocoa research institutes and governments play a key role in the following aspects:

- Provide access to a wide range of diverse cacao genetic resources and to information on these resources.
- Build trust between partners by providing information to facilitate rationalization.

- Create awareness of the importance of sharing responsibility for the conservation and use of cacao diversity.
- Seek a dialogue with decision-making political/administrative bodies in the country.
- Work towards the development and implementation of access and benefit-sharing legislation that is conducive to CacaoNet's proposed policy.
- Facilitate implementation of agreed safe-movement guidelines and cacao quarantine regulations.
- Seek funding opportunities, provide advice and develop project proposals with partners.
- Pro-actively create mechanisms and structures that allow and facilitate funding opportunities to be used.
- Actively engage in CacaoNet.

4. Our plans for the next decade

The Global Strategy consists of eight key components, as illustrated in Figure 5 and detailed in Sections 3.1 to 3.8, which together will achieve the overall objective of optimizing the conservation and facilitating the use of cacao genetic resources.

Although many of the strategic components are at least partially funded at the present time by various public and private sources in the short term, CacaoNet provides a means to better coordinate these activities and a route to the establishment of the long term stable funding base which is so urgently needed.

The Global Strategy includes an agreed workplan (Sections 4.1 to 4.8) to implement activities in the eight strategic components in the next three years (short-term actions) and beyond (long-term actions). It includes estimates of the resources required to implement the workplan and proposed indicators to monitor and evaluate progress. In the eventuality that it is not possible to secure the funds needed to fully implement the Strategy at the outset, the highest priority will be given to ensure that valuable genetic resources that are currently held in *ex situ* collections in the public domain are conserved and remain available for distribution to breeding programmes via intermediate quarantine.

The monitoring of progress towards the implementation of the Global Strategy and the achievement of its objectives and outputs is coordinated by CacaoNet. The workplan will be adjusted on an on-going basis as new information becomes available and priorities evolve.

The cost estimates presented here are based on a number of information sources:

1. the CacaoNet survey of *ex situ* collections carried between 2008-2012, which included cost estimates for collection management (see Annex 2, question 37),
2. a costing study carried out in 2009 on the CATIE collections including the cacao collection (Girón Aguilar, 2010),
3. cost estimates of managing the collection at CRU/UWI, the ICQC,R and ICGD projects provided by the managers in 2012,
4. experts' opinions on specific costs of research activities and,
5. the CGIAR Costing study 2011. The estimated cost of the development and management of the GSCC (germplasm management activities) is based on a costing study carried out between 2009-2011 of the 11 CGIAR Centre genebanks, managing international collections of several seed and vegetatively propagated crops (CGIAR, 2011).

The CGIAR study represents the most comprehensive and recent costing study of *ex situ* collections managed under international standards (See Annex 8). Proposal to the CGIAR Fund Council, submitted in 2011 by the CGIAR Consortium Board of Trustees, for financial support to the CGIAR center genebanks.

The data used for estimating the cost of managing cacao collections is taken from cost estimates of the following vegetatively propagated crops maintained in the respective CGIAR centres: banana at Bioversity and IITA, cassava at CIAT and IITA, potato at CIP, sweetpotato and Andean roots and tubers at CIP and yam at IITA.

The 2009 costs were adjusted for inflation at a rate of 5% per year and derived from the Decision Support Tool for Genebank Management, developed by the CGIAR genebanks[6]. Details of the specific costs can be found in Annex 11 (Data summarised from the Tables of Centre x Collection cost for 2009 (adjusted where needed) as derived from the Decision Support Tool (Annex 5 of the CGIAR proposal), from the CGIAR 2011 costing study).

4.1 Securing existing *ex situ* cacao genetic resources and their distribution

The first priority is to develop a sustainable funding mechanism for the most critical activities of the Global Strategy. CacaoNet together with the partners in the Global Strategy will raise awareness of the most urgent needs of international and national collections as well as all the partners to collaborate in adding value to the unique and valuable germplasm to maximise its use in producing improved planting materials. It will work together with the Global Crop Diversity Trust to develop an endowment fund targeting the conservation and use of the GSCC in perpetuity.

The Global Strategy provides a clear framework for public and private sector investment in securing the availability of cacao diversity in perpetuity in the most cost-effective manner. CacaoNet will use the priorities and actions agreed in this Global Strategy to identify sources of funding and discuss with potential donors the best mutually beneficial invest-ments to be made. Donors may wish to fund very specific, one-off research activities or specific partners, while others might be interested in contributing to securing forever the GSCC through contributions to an endowment fund.

Its short-term action will therefore be to develop a detailed fund-raising strategy and will engage in dialogues with donors to secure funding for its short-term and longer-term objectives. It is anticipated that the funding allocation guiding principles and criteria adopted by the Global Crop Diversity Trust will be followed (as proposed in Section 3.1). These activities will be coordinated by the CacaoNet Steering Committee.

Estimated budget:

The proposed budget for the resources mobilization activities is included in Section 4.8 (Strengthening the networking and partnerships for global collaboration) in the budget allocated for CacaoNet coordination and Steering Committee functions (150,000 USD/year).

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[6] The decision-support tool was developed as part of the World Bank funded project “Collective Action for the Rehabilitation of Global Public Goods in the CGIAR Genetic Resources System, Phase 2 (GPG2) 2007-2010. See: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=45&Itemid=142&lang=english

4.2 Developing the Global Strategic Cacao Collection (GSCC)

CacaoNet will coordinate the development and establishment of a Global Strategic Cacao Collection (GSCC) as a virtual collection consisting of the most unique and valuable materials according to agreed practices and standards and readily available to any *bona fide* user. The GSCC will be based on materials from the two international collections at CATIE and CRU/UWI which have placed their cacao germplasm under the auspices of the Governing Body of the ITPGRFA, the national collections that have proven records of making materials available and in public domain, such as the collections at CIRAD and USDA and from any collections willing to take the necessary steps to make their materials available particularly for use on breeding programmes. The GSCC will also rely on the critical role of the ICQC,R for the international safe movement of cacao genetic resources throughout the world.

The objective of the GSCC is therefore to ensure the cost-effective and efficient long-term *ex situ* conservation of the cacao genepool and its accessibility to all current and future users. Agreed criteria of genetic diversity richness and uniqueness, and measures of agronomic value to be used to identify priority accessions are described in Section 3.2. The process of developing the GSCC is represented in Figure 6.

The GSCC materials should be prioritized for distribution. Collection managers and breeders using the material would participate in comprehensive characterization, evaluation and further researching of the GSCC collection. All related information will be made available through GSCC information portal. The feasibility of using *in vitro* culture and cryopreservation will be considered for cost-effective duplication of the GSCC.

The consultation process for the development of the GSCC would be led by CacaoNet with all its members and with INGENIC and would take place over a number of consultation meetings. Long-term funding will be discussed with the Global Crop Diversity Trust, other international donors and with the private sector (see Section 4.1).

The following specific actions are proposed:

Short-term actions – in the next three years

- Agreeing on the criteria for the selection of materials (for both allelic diversity and traits of interest for breeding).
- Assessing the cacao genetic diversity currently conserved in *ex situ* collections.
- Identifying those publically maintained unique accessions that are available for use by breeders and researchers in the two international collections at CRU/UWI and CATIE and in national collections.
- Developing a proposal for reducing duplication of genetically similar clones, using genetic diversity assessment tools, with a focus on the collections at CRU/UWI and CATIE.

- Developing a process for resolving mislabelling problems in the international and national collections.
- Agreeing on the sharing of responsibilities for conserving and distributing the GSCC materials between the cacao collections in the public domain (roles and responsibilities of the network of partners).
- Identifying urgent conservation support needed for the material identified for the GSCC.
- Characterizing public domain germplasm prioritized to allow assessment and recommendations for inclusion in the GSCC.
- Agreeing on field evaluation at multiple sites under controlled and recorded conditions for the proposed GSCC accessions (see Section 4.4 below).
- Conducting a feasibility study on *in vitro* methods to facilitate distribution through quarantine facilities, including recommendations on type of materials (budwood or plantlets), impact and costing.
- Agreeing on the safety-duplication of the GSCC in field genebanks and/or via cryopreservation (roles of implementing partners and network of collections).
- Agreeing on the development of CANGIS (see details in Section 3.7).
- Conducting a detailed costing study of the GSCC with conservation costs and associated services such as germplasm evaluation, quarantine, virus-indexing, distribution and documentation.
- Promoting/holding continued discussions with the Global Crop Diversity Trust and with the private sector for possibilities of long-term funding support to the GSCC.
- Promoting/holding continued discussions with the Secretariat of the International Treaty and countries maintaining cacao materials targeted by the GSCC, to promote the designation of this germplasm under the Treaty following the example of CATIE and CRU/UWI.
- Agreeing on best practices for cacao collection management and develop standards.
- Promoting the implementation of genebank management standards and dissemination of germplasm and related information.

Long-term actions - beyond three years

- Continuing coordination of the GSCC including support for documentation.
- Continuing effort to characterise and evaluate germplasm in international (priority) and national genebanks towards the establishment of GSCC.
- Identifying duplicates based on characterisation of priority materials.
- Rationalizing international and national collections within the framework of the GSCC.

- Identifying a priority set of accessions for *in vitro* culture to facilitate distribution through quarantine facilities, if the feasibility study validates the use of this technology.
- Ensuring the safety-duplication of the GSCC using appropriate methodology.

In order to provide exact costing figures, a detailed and comparable costing study of CATIE and CRU/UWI cacao genebank operations and an analysis of duplication should be carried out, using the tool developed by the CGIAR, as well as an assessment of the diversity currently conserved in all collections. Therefore, the budget required for the development of the GSCC is calculated here based on estimated costs, estimated number of accessions and activities to be carried out by a network of partners.

The GSCC will be composed of accessions representing the cacao genepool based on allelic richness and on key traits of interests to breeders (criteria described in Section 3.2). The estimated number of accessions is mainly based on the CATIE collection (1146 accessions) and CRU/UWI collection (2400 accessions), and additional unique materials in other currently publicly available collections such as USDA (estimated 200 accessions) and CIRAD (French Guyana and Montpellier) (646 accessions), current total in the public domain is estimated at about 4400 accessions. If we estimate that a 10% level of duplication may exist within each of the collections (440 accessions) and 30% level of duplication between these accessions (about 1300 accessions), it is estimated that the GSCC would initially comprise of between 2500 to 3000 accessions (about 12% of the current global holdings 24,000 accessions) and would gradually be reduced as research on germplasm identity progresses and priorities are further defined. It is therefore proposed that cost estimates for the development and management of the GSCC be based on an estimated 2500 accessions.

The estimates used for costing the GSCC are based on the collection management activities defined in Annex 10 (Definition of cacao collection management activities following the model of the CGIAR Decision-Support Tool, Table 4 of the CGIAR costing study) and the specific costs detailed in the 2010 CGIAR costing study for the vegetatively propagated crops (adjusted for inflation at a rate of 5% per year). The calculations are explained in the footnotes for each cost estimate in Annex 11 (Summary of the costs of the GSCC with footnotes detailing the data source).

It should be noted that the techniques used to introduce cacao accessions into *in vitro* culture as somatic embryos for the purposes of multiplication, distribution and cryopreservation are rather different to those already widely used for other vegetatively propagated crops. Research is ongoing into improving the applicability of somatic embryogenesis techniques for a wider range of cacao genotypes and it is anticipated that the review of multiplication of planting materials currently being undertaken by Bioversity will provide updated information on the prospects and costs of such techniques. Meanwhile the costs of preparing somatic embryos of an estimated 75 accessions per year and then subsequently introduced and maintained (target 50 accessions) in cryopreservation is estimated at 1,000 USD and 500 USD respectively per accession (estimated based on the experience at Reading University). The cost of maintenance in cryopreservation in a flask (minimum containing 500 accessions) is estimated at 2000 USD per year.

Table 7. Summary of the annual costs of the GSCC – including capital costs (USD).

Operation (as described in Annex 10)	No of accessions / year	USD / year
Acquisition	20	5,620
Field maintenance	2,500	102,678
Characterization - morphological	200	5 000
Characterization - molecular	200	22,000
Identification of duplicates and integrity	200	41,200
Regeneration	200	22,600
Health testing	200	67,600
ANNUAL COSTS - based on 2009 estimates	TOTAL	266,698
ANNUAL COSTS 2012 adjustment for inflation at 5% per year	**TOTAL**	**308,736**
Introduction/ multiplication of accession *in vitro*	75	75,000
Cryopreservation (introduction)	50	25,000
Cryopreservation (maintenance)	Up to 500	2,000
GRAND TOTAL		**410,736**

Estimated budget:

- **410,736 USD annual budget** for the development and management of the Global Strategic Cacao Collection.

Notes:

It is anticipated that the annual cost would be reduced over time as the size and composition of the GSCC is revised following the diversity analysis study. On-going efforts to conserve much of the material which will initially form the GSCC are currently supported by public and private sector funding for the ICG,T and CATIE, representing an estimated 80% of the GSCC, though this is only assured on a short-term basis.

The budget for coordination of and consultation for the development of the GSCC is included in Section 4.8. Strengthening the networking and partnerships for global collaboration, in the budget allocated for meetings of the CacaoNet Working Groups and stakeholders consultations (150,000 USD/year). Support for national partners is also included in Section 4.8.

4.3 Genetic diversity gap filling in *ex situ* collections and collecting

Several diversity analyses have been and are being carried out with very specific objectives, looking at parts and components of the global diversity of cacao. Many previous collecting expeditions, especially those prior to the 1980s, have focused on collecting germplasm from individual trees showing desired agronomic traits such as disease resistance. The proposed activities will build on the current knowledge from the considerable efforts put into the SSR analysis over the past 10-15 years, and will identify the gaps in knowledge of the global cacao genepool, assessing the current technology and/or the results available for their adequacy for the purpose of creating a GSCC and carry out the complementary research needed. This will include identifying the most urgent and threatened collecting sites to fill the gaps in the existing diversity in collections and to collect materials in areas that have not yet been explored, collected from, or where the material collected does not fully represent the diversity present. It will contribute to the development of an early warning system to draw attention to threats to wild cacao germplasm or traditional varieties. A number of urgent and threatened areas, mainly due to intense deforestation, have been identified in Bolivia, Brazil, Peru and Venezuela and specific gaps are described in Section 3.3 as well as priority collecting sites in areas not adequately covered by previous collecting missions [Guyana (Plateau), Brazil (Amapá, Roraïma), French Guiana, Suriname, Venezuela and Colombia (Amazon region)]. Specific landraces have been identified as priority for conservation and for a large-scale collecting mission and comprehensive study. Future collecting missions should have the objective to safeguard alleles in populations and sub-populations.

The following specific actions are proposed:

Short-term actions – in the next three years

- Assessing and analysing the diversity of the cacao genepool in the centre of diversity *in situ* and on-farm as a priority (Upper Amazon and Mesoamerica), including understanding the threats to genetic erosion.
- Assessing the cacao genetic diversity conserved in *ex situ* collections and identification of gaps.
- Identifying geographic area of threatened genetic diversity *in situ* and on-farm and collecting priorities.
- Collecting to fill in gaps in *ex situ* collections, focusing on threatened wild related species and landraces materials.
- Setting up of a CacaoNet Working Group on planning new collecting actions in close consultation with the authorities of countries concerned on the basis of threat information and gap analysis and identify funding for carrying out collection trips,
- Developing and agreeing on a standardized collecting form to facilitate the uniform entry of data into collection management databases.
- Implementing new collecting actions on endangered traditional varieties.

Long-term actions - beyond three years

- Promoting the establishment of a mechanism to identify and communicate threats to cacao genetic resources (vulnerability and erosion) at national and international level, where relevant in close collaboration with FAO.
- Further collecting actions on endangered wild cacao germplasm, wild germplasm that has not yet been placed in *ex situ* collections and related *Theobroma* and *Herrania* species.

The research should be carried out by a team of experts with complementary skills in taxonomy, diversity analysis and conservation of genetic resources *ex situ* and *in situ*. Such research projects should be coordinated by a lead institute with an interest and already investing resources in this area of research. It would involve (and benefit) primarily the national programmes in the centre of origin (support to *in situ* conservation and collecting). CacaoNet would play a role in ensuring participation of key stakeholders and that capacity is built in diversity analysis in the partners with conservation responsibilities in the centre of diversity of cacao. The assessment of the genetic diversity currently in *ex situ* collections would involve field and lab work such a running DNA fingerprinting and analysis. Such a study would involve planning, implementing, running DNA fingerprinting, and interpreting the results (accessions collected) where the costs can be as high as 40,000 dollars for 100 new genotypes. This work would follow on from ongoing efforts by research institutes, USDA, CIRAD and industry to analyse the diversity of the cacao genepool held *ex situ*. The estimated budget of 650,000 USD for a 3-year project is based on experts carrying out this type of project at USDA and INIAP, Ecuador.

An annual budget for priority collecting missions, estimated for 200 samples/year (at a unit cost of 150 USD) and travel/equipment at 10,000 USD.

Estimated budget:

- **650,000 USD for a three-year project** on diversity analysis.
- **45,000 USD annual budget** for priority collecting missions.

4.4 *In situ* and on-farm conservation of important genetic diversity

The distribution and diversity of the cacao genetic resources *in situ* and on-farm is not well understood and collections are hence limited. A greater effort is needed to understand this diversity and develop strategic plans that take into consideration the socio-economic and biological determinants that influence decisions about the conservation and use of particular varieties in famers' communities. The aim of such conservation strategy is to safeguard genetic resources from being lost from the wild and on-farms and to engage the participation of national partners in the areas of highest diversity of cacao.

The following specific actions are proposed:

Short-term actions – in the next three years

- Actions to understand the level/extent of genetic erosion of *in situ* and on-farm diversity, in centres of diversity of cacao. Activities will include surveying the status and establish an inventory of landraces and traditional varieties in Upper Amazon and Mesoamerica and developing scientific methodologies to assess the impact of genetic erosion of on-farm genetic diversity.
- Analyze the social, economic, market and cultural factors that influence farmers' maintenance of cacao diversity at the farm level and assess their implications for designing *in situ* and on-farm conservation strategies.

Long-term actions - beyond three years

- Develop *in situ* and on-farm conservation strategies, including analysis of social economic, market and cultural factors influencing on-farm management and incentives such as Payments for Agro-Biodiversity Conservation Services (PACS).
- Assessing the needs for *in situ* and on-farm conservation strategies for countries and regions located in the cacao historical dispersal routes, especially the areas surrounding harbours known for their role in germplasm transit, such as Samoan islands, São Tomé and Príncipe, Reunion Island, Fernando Po Island, Sri Lanka etc. Germplasm in such locations could be considered as being at particular risk as the cocoa sectors surrounding them are in significant decline.
- CacaoNet to develop strategic alliances and foster a synergistic partnership amongst government agencies, science research institutions, NGOs and farmer communities for integrated regional development planning and implementation, including the designing of national forest reserves, wildlife refuge, private reserve and ecotourism.

Estimated budget:

- **450,000 USD for a three-year project** on the development of *in situ* and on-farm conservation strategies.

4.5 Strengthening the distribution mechanism and safe movement of germplasm

The objective of this strategic area is to facilitate the use of the GSCC materials by ensuring their safe distribution, considering the serious risks of spreading pest and diseases in new areas causing significant crop losses. This activity will consist of promoting the updated 2010 Safe Movement Guidelines and ensuring that international and regional quarantine facilities have the necessary means and capacity to ensure that the most interesting and valuable material can be used by all interested breeding programme and other scientists in all parts of the world. The CacaoNet Working Group on Safe Movement will play an important role in updating the guidelines as new information becomes available on cacao pests and diseases and also consider new technologies as they become available.

CacaoNet will coordinate the consultation process towards the development of regional quarantine centres to complement the role of securing international movements through the ICQC,R, facilitating regional exchange of between countries where the same cocoa pest and diseases are endemic.

CacaoNet will continue to work with closely national programmes, FAO, the Global Crop Diversity Trust and the International Treaty to promote the placing of cacao germplasm in the public domain through designation under the Treaty, so that more diversity is freely available to bona fide users and exchanged legally, transparently and fairly, through the use of a MTA.

The following specific actions are proposed:

Short-term actions – in the next three years

- Supporting the maintenance and continued development of a network to facilitate the safe movement of cacao. This includes the ICQC,R, UK for international distribution, and regional facilities, to be established within institutes with quarantine facilities willing to play this role in the three regions.
- Engaging with the International Plant Protection Convention (IPPC) with the intention of getting acceptance from this organization for the CacaoNet guidelines for the safe movement of cacao germplasm in order that they can be promoted by its Regional Plant Protection Organizations.
- Exploring the feasibility of using *in vitro* methods for germplasm distribution through a research project.
- Raising awareness of the new safe-movement guidelines through circular e-mails, INGENIC, COPAL conference etc. and set up additional web-links to the Bioversity and CacaoNet web pages that hosts the Safe Movement publication. Send out copies of the publication on a CD.
- Reviewing the guidelines after two years (or when significant new information becomes available), incorporating new technologies and any changes that have taken place regarding technologies and the distribution of pests and diseases.

Long-term actions - beyond three years

- Reviewing the guidelines after four years and incorporating any changes that have taken place regarding technologies and the distribution of pests and diseases.
- Publishing the guidelines in French, Spanish and Portuguese.

These activities would be coordinated by CacaoNet and the estimated budget for coordination is included in the Section 4.7. Although the costs for running the ICQC,R are known, the costs involved in setting up and maintaining three regional facilities have been estimated based on the assumption that a total of 150 accessions would be handled between three regional facilities, making up the cacao safe movement network. Further research is needed on the use of *in vitro* methods for germplasm distribution and a research project is proposed involving the partners to be involved in international and regional movement of germplasm. The project would include training and capacity building elements. It is anticipated that prioritisation of germplasm for international transfer and the implementation of new technologies for the screening and distribution of cacao material should reduce the cost of safe movement of germplasm within the next few years.

Estimated budget:

- **100,000 USD for a three-year research project** on tissue culture for safe movement.
- **150,000 USD initial costs** for the establishment of the regional quarantine network.
- **327,000 USD annual budget** for the development and maintenance of the cacao safe movement network (including the ICQC,R and the Regional facilities).

Notes:

An estimated 75% of these costs of the current safe movement network are presently provided by USDA/CRA Ltd. who provide support for the ICQC,R project. It is anticipated that these costs might change as new technologies are implemented and as new priorities for germplasm distribution come into effect.

The budget for the functioning of the CacaoNet Working Group on Safe Movement and the consultation for the development of regional quarantine facilities is included in Section 4.8 (Strengthening the networking and partnerships for global collaboration), in the budget allocated for meetings of the CacaoNet Working Groups and stakeholders consultations (150,000 USD/year).

4.6 Strengthening the use of the cacao genetic resources

The objective is to maximise the use of cacao germplasm by providing support to breeders and key users through improved characterization, evaluation within collections and supporting population enhancement programmes. The priority is therefore the evaluation for economically important traits of accessions in the GSCC such as yield, disease resistances, precocity, tree size (quality and vigour) establishment ability and drought tolerance. Further prioritization on specific traits will be required under the coordination of CacaoNet in consultation with INGENIC.

This would consist of an international multi-site evaluation programme, in collaboration with INGENIC and the regional breeding networks. CacaoNet would play a facilitating/coordination role. The network of evaluation trials would agree on standards and methodology for evaluation and documentation. Information would be shared and made publically available through the GSCC information portal.

The material with interesting traits would be made available to interested breeding programmes and promoted by making the information readily available via the GSCC information portal (linking ICGD and GREST). The proposed activities will build on current germplasm enhancement or pre-breeding programmes such as the ones implemented by CRU/UWI and CATIE, including continuing to make available the best selections through the ICQC,R.

The following specific actions are proposed:

Short-term actions – in the next three years

- Supporting a network of field trials participating in the evaluation of the GSCC materials at multiple sites. This would include distribution of material following the Safe Movement Guidelines (through international and regional quarantine facilities or *in vitro* where appropriate), introduction into field sites, evaluation, information and distribution regionally or locally.
- Developing or improving, if necessary, reliable and standardized evaluation methods for major agronomic traits.
- Identifying the most useful GSCC germplasm for distribution, adapting to the evolving needs of breeding programmes, such as the CFC/ICCO/Bioversity collection, the black pod and witches' broom enhancement programmes in CRU/UWI and frosty pod in CATIE. This will be an important part of the material for priority conservation and distribution in the GSCC.
- Making available a list of the main traits of accessions held in the ICQC,R which will help breeders prioritize their germplasm requests and assist them in locating material from local genebanks for inclusion in their breeding trials.
- Maintaining the black pod and witches' broom enhancement programmes in CRU/UWI and frosty pod in CATIE, and continue to make available the best selections to the ICQC,R.

- Introducing accessions with diverse resistance to witches' broom and frosty pod into West Africa and into South-East Asia breeding programmes.

Long-term actions - beyond three years

- Continuing evaluation of GSCC materials of interest to breeders.
- Continuing the germplasm enhancement programmes at CRU/UWI and CATIE and ensure the best selections continue to be made available via international and regional quarantine facilities.

This international multi-site evaluation programme would build on experience of the CFC/ICCO/Bioversity project field trials but will take account of developments in establishing better methodologies for evaluation of yield determinants and adaptation to planting density. The programme would be carried out through a network of partner institutes with specific interest in evaluating part of the GSCC and with capacity to carry on this work. The programme would consist of evaluation trials in each of the Africa, Asia and Latin America/Caribbean Regions, with a proposed four sites per Region, with different environmental, biotic and abiotic conditions.

Suggested activities budgeted would be:

- Distributing promising materials for multi-location evaluation trials.
- Nursery multiplication and field planting of materials.
- Evaluating and selecting established variety trials.
- Exchanging information and disseminating results.
- Disseminating interesting germplasm through intermediate quarantine to user countries

The cost is estimated on the CFC/ICCO/Bioversity project and figures from recently established breeding trials in Ghana.

Estimated budget:

- **300,000 USD annual budget** for international multi-evaluation sites.

4.7 Improving the documentation and sharing of information on germplasm

The objective is to develop a portal for accessing all relevant information and be a key component in the establishment, management and use of the GSCC. This GSCC information portal will document all data related to the conservation, evaluation and management of the germplasm and would be made publically available at all times. This includes building on its central database CANGIS, linking to the ICGD, TropGENE and all the genebanks and service providers that collectively form the GSCC, with newly developed GRIN-Global. Users will be able to access information on individual trees located at specific sites (GSCC accessions) and their availability. This will include some capacity building of key collections to develop or adopt new local genebank management systems (such as GRIN-Global) to ensure a minimum standard of record keeping. This may involve a minimum level of hardware (computers and networking) and general skills in information technology. Information would be recorded on movement of GSCC accession from one location to another including the quarantines (See Figure 7). The GSCC information portal would also provide the users with the possibility to request material on-line through a germplasm ordering system with MTAs. The CacaoNet website will provide a single point for accessing information on GSCC, and provide a basic overview of cacao and its importance globally, highlighting public awareness issues.

The following specific actions are proposed:

Short-term actions – in the next three years

- Coordinating the compilation of characterization and evaluation data from all collections (data to be supported by the molecular verification of genotypes where possible) to facilitate the identification of the GSCC including breeding and evaluation data.
- Developing the GSCC information portal, including CANGIS in particular, by requesting information from the international collections held by CRU/UWI and CATIE (e.g. accession and tree numbers and passport data not already maintained by existing databases), including information on the collection at ICQC,R, adding links and web services to other online databases and contact details to request material.
- Introducing tree identifiers and accession numbers to ICGD, allowing specific evaluation data in the ICGD to be linked to CANGIS.
- Stimulating the rescue of historical data collected in genebanks and eventually trials which can provide information useful to breeders.
- Developing automated system for monitoring and updating the GSCC information portal, with particular emphasis on linking local systems to CANGIS.
- Developing a germplasm ordering and tracking systems.
- Making CANGIS available to cacao community (online) and request feedback.

- Assessing the suitability of adopting GRIN-Global at collections that do not have a local information management system already by assessing minimum level of local expertise and IT equipment needed and the training requirements for initial set up (customization).

Long-term actions - beyond three years

- Ensuring appropriate level of record keeping in collections (working at tree level) and potential uptake of GRIN-Global.

The development of the GSCC information portal will initially focus on compiling characterisation and evaluation information on *ex situ* cacao germplasm for the identification of priority materials for the establishment of the GSCC. The identification of the unique materials would be done through an analysis of duplicates based on characterisation data. Support would be provided to cacao collection institutes (genebanks) for linking information to the GSCC information portal at an estimated 15,000 USD per genebank for at least 10 collections. The cost estimate is based on the initial cost of development of CANGIS, the support to cacao collections for linking to the GSCC information portal (including CANGIS) and the annual management of the system. The development and maintenance of the GSCC information portal includes support towards the ICGD, TropGene, GRIN-Global and local germplasm management systems in some of the collections with GSCC accessions. An estimated 40% of these costs are currently covered by NYSE Liffe/CRA Ltd who provides support for the ICGD project. These costs may decrease with time as the information systems are established and information management capacity is built within national genebanks.

Estimated budget:

- **250,000 USD annual budget** for support for genebanks linking to GSCC information portal, the maintenance and further development of information network for CacaoNet, including ICGD and CANGIS

4.8 Strengthening the networking and partnerships for global collaboration

The Global Strategy depends on increasing the capacity of national partners to play a key role in ensuring the conservation and use of the genetic diversity. Developing and promoting the use of best practices would ensure sustainability in the management of cacao collections. The capacity building will involve providing training and equipment support to the collection partners in the GSCC. The key areas of capacity building are: cacao germplasm collection management, germplasm characterisation and evaluation, information management and data analysis (including diversity, gap and collecting priorities). These activities will improve the documentation of information related to cacao germplasm in all *ex situ* collections including the adoption of GRIN-Global, addressing the urgent issue of mislabelling. It will promote the availability of material in the public domain and participation in evaluation trials of GSCC materials. It will support the organisation of regional and global workshops based on most critical needs of the national partners. A capacity building and training budget is proposed for the partners in the GSCC, estimated at 10% of the total Global Strategy costs. In addition to training, urgent support to threatened collections would be provided through an emergency fund estimated at 50,000 USD per year.

CacaoNet will play a key role in overall coordination and monitoring of the implementation of the Global Strategy. It will ensure agreement on the establishment of the GSCC and is functions on behalf of all its members. CacaoNet and its partners will actively engage in fund-raising for the implementation of the Global Strategy, including involvement of the private sector and international funding agencies such as the Global Crop Diversity Trust to leverage funding for cacao genetic resources and establish the endowment fund. CacaoNet will encourage collaboration with national collections, FAO and the International Treaty to promote the placing of germplasm, particularly accessions identified for inclusion in the GSCC, in the public domain.

CacaoNet will establish the following four Working Groups:

1. Partnership for conservation - the development of the GSCC.
2. Diversity analysis and *in situ* conservation.
3. Use and safe movement of germplasm.
4. Documentation and information management.

The main tasks of the CacaoNet Working Groups will be to monitor the implementation of the respective components of the Global Strategy and develop project proposals for research, methodologies and development of tools. Each Working Group will include experts and key stakeholders.

CacaoNet's Steering Committee will oversee the efficient function of the Network and be responsible for carrying out activities related to resource mobilization and fund raising.

The CacaoNet Secretariat, hosted by Bioversity, will ensure the coordination, the dissemination of information and organization of expert consultations. It will engage with and report to donors supporting the implementation of the Strategy.

Estimated budget:

- **150,000 USD annual budget** for training and capacity building of partners estimated at 10% of the total annual costs of the Global Strategy.
- **50,000 USD annual budget** for emergency support to safeguard threatened material (*in situ* and *ex situ*).
- **150,000 USD annual budget** for meetings of the CacaoNet Working Groups and stakeholders consultations.
- **150,000 USD annual budget** for CacaoNet coordination and Steering Committee functions.

CacaoNet consultation meeting, July 2011, Reading, UK (K. Lamin, MCB)

4.9 Summary of budget requirements for the global strategy implementation

Funding for the conservation and use of cacao genetic resources is currently provided by the many national research institutes (with the help of the cocoa industry, public funds from consuming countries, and international organisations) and is below optimal levels. Support for the two international collections at CATIE and CRU/UWI and to the ICQC,R is offered on a three-year cycle and is not secure over the long term. Many national collections are struggling to keep their material alive.

In order to safeguard the security of cacao diversity, on which the world depends for cocoa production now and in the future, and to ensure its accessibility and sustainable use, the Global Strategy has estimated the funds required for its implementation based on two types of costs: (1) cost of annual recurrent management activities and (2) cost of one-off initial research and capacity building activities to bring the global system to the required international standards.

In the eventuality that it is not possible to secure the funds needed to fully implement the Strategy at the outset, the highest priority will be given to ensure that valuable genetic resources that are held in *ex situ* collections in the public domain are conserved and remain available for distribution to breeding programmes via intermediate quarantine

The annual recurrent management activities are the following:

- Support for the on-going maintenance of the GSCC.
- Emergency support to safeguard threatened material.
- Management of the GSCC information portal.
- Maintenance of the cacao safe movement network (quarantine facilities).
- Support for priority collecting missions.
- Network of field evaluation trials of priority GSCC materials.
- Training and capacity building for GSCC partners.
- Global partnerships towards the Strategy implementation.

The research and capacity building activities over the first three-years:

- Support for the *ex situ* collections partnering with the GSCC for linking to the GSCC information portal.
- Development of *in situ* and on-farm conservation strategies.
- Diversity analysis to complement existing knowledge and to identify gaps for priority collecting.
- Research on tissue culture methods for safe movement of germplasm.
- Establishment of the regional quarantine network.

The costs of the annual recurrent management activities is estimated at 1,832,736 USD, though it is anticipated that these costs will be significantly reduced over time as the size and composition of the GSCC are refined as a result of the proposed genetic diversity analysis and improvements to the efficiency with which germplasm can be conserved and distributed following research on *in vitro* methodologies and as new priorities for germplasm distribution come into effect. The total costs for this initial research on the most efficient and effective conservation and management standards, and the resources needed to bring the capacity of partners up to a state where they can play an international role, are approximately 1,350,000 USD for a 3-year period.

Table 8. Summary details of the annual recurrent costs.

Annual recurrent activities	USD / year
Development and management of the Global Strategic Cacao Collection (GSCC) (details in Section 4.2) **NOTE:** It is anticipated that this figure would be reduced over time as the size and composition of the GSCC is revised following the diversity analysis study. On-going efforts to conserve much of the material which will initially form the GSCC are currently supported by public and private sector funding for the ICG,T and CATIE, representing an estimated 80% of the GSCC, though this is only assured on a short-term basis.	410,736
Annual collecting missions to rescue threatened materials (See details in Section 4.4)	45,000
Network of field evaluation trials of GSCC materials (details in Section 4.5) **NOTE:** Some ongoing evaluation activities are already supported in the national and international genebanks.	300,000
Support for genebanks linking to GSCC information portal, the maintenance and further development of information network for CacaoNet, including ICGD and CANGIS(details in Section 4.6) **NOTE:** An estimated 40% of these costs are currently covered by NYSE Liffe/CRA Ltd who provides support for the ICGD project. These costs may decrease with time as the information systems are established and information management capacity is built within national genebanks.	250,000
Management of the cacao safe movement network (including the ICQC,R and the Regional facilities) (details in Section 4.7) **NOTE:** An estimated 75% of these costs are currently provided by USDA/CRA Ltd. who provide support for the ICQC,R project. It is anticipated that these costs might change as new technologies are implemented and as new priorities for germplasm distribution come into effect.	327,000
Capacity building and training support to partners in the GSCC, estimated at 10% of the total annual costs of the Global Strategy (details in Section 4.8)	150,000
Emergency support to national collections (details in Section 4.8)	50,000
Global partnerships for monitoring progress towards the Global Strategy implementation – meetings of the Working Groups and stakeholder consultations (details in Section 4.8)	150,000
CacaoNet coordination and Steering Committee functions (See details in Section 4.8)	150,000
TOTAL	**1,832,736**

Table 9. Summary details of the one-off costs.

Research projects and initial developments	USD
Research project on diversity analysis of the cacao genepool, concomitant threats, and filling in gaps in conservation (details in Section 4.3) - 3 years **Note:** This work would follow on from ongoing efforts by research institutes, USDA, CIRAD and industry to analyse the diversity of the cacao genepool held *ex situ*.	650,000
Research project on the development of *in situ* and on-farm conservation strategies (details in Section 4.4) – 3 years	450,000
Establishment of the regional quarantine network (details in Section 4.5) – initial costs	150,000
Research project on tissue culture for safe movement (details in Section 4.5) – 3 years	100,000
TOTAL	1,350,000

4.10 Monitoring and evaluation of the implementation

The goal of the Global Strategy is to optimize conservation and maximize use of cacao genetic resources, as the foundation of a sustainable cocoa economy (from farmers, through research, to consumers) by bringing together national and international players in both the public and the private sectors. The Global Strategy promotes the rationalization of conservation efforts at regional and global levels by encouraging partnerships and sharing facilities and tasks. A number of indicators are proposed in Table 10 to monitor progress of implementation towards achieving the Global Strategy outputs, to be monitored by CacaoNet:

Table 10. Global Strategy outputs and related proposed indicators for monitoring progress of implementation.

OUTPUTS	Indicators for monitoring progress and impact
Output 1: The cacao genepool is conserved *in situ* and *ex situ* for the long term by a global network of partners maintaining the most important diversity of cacao genetic resources. Based on priorities and protocols for identifying accessions, ensuring the safety-duplication of unique material, facilitating the rationalization of existing collections, setting priorities for collecting additional material, developing common standards for best practices and allocating resources for maintaining the collections.	Extent of the cacao genepool secured in publically available collections. Most threatened cacao germplasm is conserved in accessible national collections. Increased proportion of unique material in *ex situ* collections with formal safety duplication agreements outside the country. Reduction of unnecessary duplication of material in *ex situ* collections supported by public funding. Increased amount of cacao germplasm in the public domain available and accessible for use. Increased collaboration between collections to share responsibility in the long-term conservation of the cacao genepool. Cost-effective conservation methods promoted. Gaps in the conserved diversity identified and collection missions proposed for priority germplasm (threatened or not accessible). Agreed management standards for optimum long-term conservation and use of cacao germplasm. Increase funding for priority support to the long-term conservation of cacao genetic resources.

OUTPUTS	Indicators for monitoring progress and impact
Output 2: The global system for the safe exchange of cacao germplasm is strengthened. Based on agreed protocols (technical and legal) and resources to support quarantine, disease diagnostics, and supportive research in this area.	Increased number of partners collaborating in the exchange of cacao germplasm. Safe movement guidelines continuously updated and implemented by an increasing number of partners. Increased quarantine facilities promoting and facilitating the safe movement of germplasm to the users. Number of accessions exchanged between partners in accordance with the Guidelines.
Output 3: The use of cacao genetic diversity is optimized. Based on increased characterization and evaluation of cacao genetic resources and the sharing of information, and support to pre-breeding activities and the establishment of focused working collections.	Capacity building needs of collection managers identified with regards to promoting efficient links to breeding programmes and support provided. Increased amount of characterisation and evaluation data on cacao germplasm generated by germplasm managers and users and included in the GSCC information portal. Increased exchange (dissemination and accessibility) of information on valuable traits of cacao germplasm to users. Increased interest and participation of farmers and breeders in the cacao germplasm maintained in *ex situ* collections, verified by requests for materials for evaluation. A number of new local/regional breeding programmes started in cocoa producing countries based on available genetic diversity. Data on adoption of superior cultivars.
Output 4: The effectiveness of global efforts to conserve and use cacao genetic resources is assured. Based on effective coordination and the monitoring of the implementation of the Global Strategy, including information management and public awareness.	Long-term financial support to the key collections maintaining the Global Strategic Cacao Collection. Efficiency of CacaoNet to coordinate and stimulate participation of an increased number of key partners in the conservation and use of cacao germplasm. A Global Strategy that is agreed and supported by an increasing number of partners (donors and funders). Priorities of the Global Strategy reviewed and updated. Number of projects addressing the agreed priorities on-going or implemented

5. Annexes

Annex 1. List of participants to the Reading meeting, June 2011

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Annex 2. Template of the global survey undertaken between 2006-2011

Cacao genetic resources conservation and utilization - A global survey – 2006-2008-2011

Introduction

The Global Network for the Cacao Genetic Resources, CacaoNet, is putting together a global strategy for the conservation and use of cacao genetic resources. In order to describe the current situation as best possible, we need updated information on the status of cacao collections. As a curator and/or scientist working with a cacao germplasm collection, we kindly request you complete/update this questionnaire. It has 40 questions and will take you approximately 60 minutes. The feedback received will contribute to the Global Strategy and you will have an opportunity to review its content and provide feedback.

Please return the completed survey to Martin Gilmour by email, fax or mail to the following address:

Martin Gilmour, Cocoa Sustainability, MARS Incorporated
Tel.: +44 (0)1753 514369, Mobile: +44 (0)780 1019522, Fax: +44 (0)1753 514737,
Email: martin.gilmour@effem.com
Or to
Brigitte Laliberté by email: brig.lalib@gmail.com.

We would be grateful if you could provide an updated list of accessions for inclusion in The International Cacao Germplasm Database - ICGD, which forms a key part of the Global Strategy and CacaoNet, to help identifying unique germplasm held in collections (http://www.icgd.reading.ac.uk/index.php). This information can be sent in any format that is most convenient for you. Please send the updated accession list to Dr Chris Turnbull by email to c.j.turnbull@reading.ac.uk or a CD by mail to the following address: School of Biological Sciences, Harborne Building, University of Reading, RG6 6AS, UK.

Your participation in the development of this initiative is highly valued. If you have any questions or difficulties, please do not hesitate to contact Brigitte Laliberté or Chris Turnbull.

INSTITUTIONAL INFORMATION

1. & 2. Institute name and address

Name and address of institution holding the collection	
Name of institution	
Address	
Country	
Curator managing the cacao collection:	
Last name	
First name	
Address	
Email	

3. Please give your name if not provided in the response to Question 2

Last name	
First name	
Position	
Institute	
Address	
Email:	

4. Please indicate the type of institute that holds the collection:

- ☐ Public-funded institute (government institute, university, public-funded research institute)
- ☐ Private institute
- ☐ Other, please specify:

5. Please indicate what responsibility the institute has in maintaining the collection (only one tick per row):

	Yes	No	Don't know
Does the institute own the collection?			
Does the institute have an official mandate from the government to conserve cacao?			
Does the institute have an official mandate from the government to carry out research on cacao?			
Does the institute have an official mandate for conserving cacao at the regional or global level?			
Does the institute have sole responsibility for management decisions concerning the collection?			
Does the institute provide most or all of the recurrent costs for the collection?			

6. If you have answered "no" to any of these questions please specify, where possible, who is the responsible institute(s):

THE CONTENT OF THE COLLECTION

7. What year was the collection initiated:

8. Please estimate the number of accessions in the collection:

	Number of accessions
Number of accessions at the founding of the collection	
Number of accessions in 1990	
Number of accessions today	

9. Please describe the main objectives of the collection (in terms of conservation, breeding, dissemination):

10. Please indicate the number of accessions in the collection within the categories below:

Type of accessions	Number of accessions
Related *Theobroma* species	
Wild relatives of other genera (e.g. *Herrania*)	
Wild seedling accessions of *Theobroma cacao*	
Wild clonal accessions of *T. cacao*	
Clonal accessions selected in farms	
Seedling accessions collected from farms	
Clonal accessions selected in breeding plots	
Other (please specify):	

11. Please estimate the percentage of accessions in the following categories:

Categories	Percentage %
Local origin (native to host country)	
Regional origin (native to the host region but not the host country)	
Introduced (not native to the host region)	
Unknown origin	

12. How many, if any, accessions are there in the collection that represents safety duplicates from other cacao collections?

	Number of accessions
Number of duplicates from the same institute	
Number of duplicates from another institute in the country	
Number of duplicates from another collection abroad	
None	

13. What part of the collection (which accessions) make the collection important or unique?

14. How has the collection changed in the past 10 years? Estimated number of accessions:

	Number
How many accessions have been acquired in the past 10 years?	
How many accessions have been lost from the collection in the past 10 years?	
How many accessions have been removed as part of the rationalization or reduction of the collection?	

15. Please describe any gaps in the collection in terms of genetic diversity that would help fulfil research or breeding objectives?

16. Is there any genetic diversity in the host country, either in cultivation or in the wild, that is poorly represented in *ex situ* collections?

17. Please describe any recent efforts or future plans to collect germplasm:

GERMPLASM MANAGEMENT

18. Please indicate the number of accessions conserved in the following forms:

	Number of accessions
Field collection	
Greenhouse or nursery	
In vitro (medium-term storage)	
Cryopreservation	
Other (please specify)	

19. What is the size of the field collection?

Number of independent plots:	
Total size of field collection (in ha):	
Average number of trees per seedling progeny	
Average number of trees per clonal accession	

20. What methods of clonal propagation are used (only one tick per row)?

Methods	Mostly	Rarely	Never
Rooted cuttings			
Budded or grafted plants (under the cotyledon)			
Budded or grafted plants (above the cotyledon)			

21. What facilities are available (tick as many as appropriate)?

Facilities	Yes, on site	Yes, provided by partner institute	No
Multiplication facilities (nursery, etc.)			
Irrigation facilities			
Post-entry quarantine			
Virus-indexing			

22. To what extent are pests or diseases having an effect on the collection (only one tick per row)?

	Yes, major effect	Yes, minor effect	No effect
Affecting trees within specific accessions			
Affecting trees in a wide range of accessions			
Causing annual losses of trees			
Preventing distribution of germplasm			
Incurring costs in pest & disease control			

23. If yes, which are the most damaging pests and diseases:

24. Please estimate the percentage of original accessions in the collection that are safety duplicated:

	% original accessions in the collection
Percentage of accessions in the collection that are not duplicated elsewhere	
Percentage of accessions that are duplicated in different fields at the same site	
Percentage of accessions that are duplicated at a distant location	

25. If less than half of the collection is in safety duplication please indicate the main reasons why?

26. What activities have been carried out or are ongoing concerning the collection (only one tick per row)?

	Carried out on a routine basis	Carried out occasionally	Not carried out
Field maintenance and labelling			
Characterization for taxonomic traits (flower colour, flush colour, pod and bean size, etc)			
Characterization using molecular markers			
Evaluation of yield traits (pod and bean traits)			
Field observations of disease and pest incidence			
Screening for disease & pest resistance			
Breeding (hybrid or clonal trials)			
Quarantine of incoming/outgoing material			
Virus indexing			
Dissemination to farmers			
Germplasm exchange with other institutes			
Safety duplication for other institutes			

27. How are the data mostly managed (tick as many boxes as apply)?

	Spreadsheets	Database	Hard copy (paper)	Not collected
Passport data (name, origin, etc.)				
Photographs of accessions				
Characterization data				
Evaluation data				
Management data				
Shipment of germplasm				

28. How are the data made available (only one tick per row)?

	Regularly (once or more a year)	Sometimes (less than once a year)	Never
Upon request as electronic downloads or printouts			
On the institute web site			
Published catalogues			
Supplied to the ICGD at the University of Reading			

29. Please describe any plans, needs or constraints concerning managing information on accessions in the collection:

GERMPLASM EXCHANGE & DISSEMINATION

30. How frequently are samples of germplasm distributed from the collection (one tick per row)?

	Once or more every month	Less than once a month but at least once a year	Less than once a year
To local users			
To more distant users in the country			
To users outside the country but within the region			
To users outside the region			

31. What is the average number of accessions distributed annually?

	Average number of accessions
To local users	
To more distant users in the country	
To users outside the country but within the region	
To users outside the region	

32. Which accessions are distributed from the collection (only one tick per row)?

	Distributed locally	Distributed outside the country	Never distributed
Locally-collected accessions			
Accessions originating from outside the country			
Clones			
Seedlings			

33. What factors, if any, limit the use of materials for breeding?

34. Where possible, please indicate for what purposes disseminated materials are used

Purposes	Frequent use	Moderate use	Rare use	Never used
Research activities (taxonomy and related studies)				
Characterization				
Evaluation				
Pre-breeding				
Breeding				
Biotechnological research				
Distribution to growers				

35. What, if any, are the conditions or requirements that apply to requests for germplasm (e.g. formal or informal approval processes, agreements or any other requirements relating to the availability of germplasm)?

LONG-TERM SECURITY OF THE COLLECTION

The responses to the following questions are important in providing baseline information to estimate the costs of supporting cacao conservation at a global level.

36. What is the current status of the collection with respect to the following factors?

Factors	Very Good	Adequate	Inadequate	No opinion
Funding for routine operations and maintenance				
Number of trained staff				
Status of buildings, facilities and equipment				
Funding for collecting germplasm				
Funding for research on the collection				
Level of use by breeders, researchers or growers				

37. Please estimate the annual costs in US$ per 100 accessions of the following activities carried out on the collection.

	US$/100 accessions/year
Field collection maintenance	
Morphological characterization	
Molecular characterization	
Agronomic evaluation	
Germplasm health (indexing & eradication)	
Information management	

38. Please provide the details of any other major costs

39. What changes to the present situation would you consider to be essential for the long-term conservation of cacao at a global level?

40. Please describe the major needs or concerns influencing the long-term sustainability of the collection

Thank you for completing this questionnaire

Annex 3. List of institutes with cacao *ex situ* collections that responded to the CacaoNet survey between 2008 - 2012

Country	Institute's short name	Date of response:	Name of institution	Curator's name
Brazil	CEPEC-CEPLAC	June 2008	CEPEC/CEPLAC	Jose Luis Pires
Côte d'Ivoire	CNRA	August 2011	Centre National de Recherche Agronomique - CNRA	Tahi Gnion Mathias
Costa Rica	CATIE	February 2012	Centro Agronómico Tropical de Investigación y Enseñanza - CATIE	Wilbert Phillips
Cuba	EIC-ECICC	June 2008	Estación de Investigaciones de Cacao. Estación Central de Investigaciones de Café y Cacao - EIC-ECICC	Miguel Menéndez Grenot
Dominican Republic	IDIAF	July 2011	Instituto Dominicano de Investigaciones Agropecuarias y Forestales, Estación Experimental Mata Larga,San Francisco de Macoris	Marisol Ventura López
Ecuador	INIAP	July 2011	Cocoa and Coffee Research Programme, Instituto Nacional Autónomo de Investigaciones Agropecuarias	Freddy Amores
France	CIRAD-MPL	February 2012	Centre de coopération internationale en recherche agronomique pour le développement, Montpellier, France	Philippe Lachenaud
French Guiana	CIRAD	February 2012	Centre de coopération internationale en recherche agronomique pour le développement, French Guiana	Philippe Lachenaud
Ghana	CRIG	August 2008	Cocoa Research Institute of Ghana	Stephen Yaw Opoku
Guyana	MHOCGA	July 2008	Mabaruma/Hosororo Organic Cocoa Growers Association	Patrick Chesney
India	CPCRI	July 2008	Central Plantation Crops Research Institute	Elain Apshara. Respondent: D. Balasimha
Indonesia	Bah Lias	July 2008	Bah Lias Research Station. PT. PP. London Sumatra Indonesia	Respondent: Eben Haeser
Indonesia	ICCRI	July 2008	Indonesian Coffee and Cocoa Research Institute	Agung Wahyu Susilo
Malaysia	MCB	May 2011	Malaysian Cocoa Board	Haya Ramba. Respondent: Kelvin

Country	Institute's short name	Date of response:	Name of institution	Curator's name
				Lamin
Nicaragua	UNAN	March 2012	Laboratorio de BIOciencia / UNAN-Managua	Juan Carlos Ruiz. Respondent: Iván Marín Arguello
Nigeria	CRIN	August 2011	Cocoa Research Institute of Nigeria, Crop Improvement Division	Daniel Adewale
Papua New Guinea	CCI	August 2011	Papua New Guinea Cocoa and Coconut Institute	James Butubu
Peru	ICT	March 2012	Instituto de Cultivos Tropicales	Enrique Arévalo-Gardini
Peru	UNAS	February 2012	Universidad Nacional Agraria de la Selva	Luis Fernando García Carrión
Togo	CRAF	August 2011	Centre de recherche agronomique de la zone forestière	Komivi Exonam AMETEFE; Komlan WEGBE
Trinidad and Tobago	CRU/UWI	July 2008	Cocoa Research Unit	David Butler
United Kingdom	ICQC,R	February 2012	International Cocoa Quarantine Centre, University of Reading	Andrew Daymond
United States of America	USDA	August 2011	USDA/ARS Tropical Agriculture Research Station	Brian Irish
Venezuela	INIA	February 2012	Instituto Nacional de Investigaciones Agrícolas	Alvaro Gómez Morales

Annex 4. Details on the cryopreservation methodology

Cryopreservation, the storage of propagules in liquid nitrogen at ultra-low temperatures, is increasingly being used to enhance the security of crop germplasm collections and offers also a complementary way to conserve cacao. Somatic embryos currently represent the most appropriate target propagules for preservation of cacao germplasm. Some success with cryopreservation of isolated immature zygotic embryos was reported (Pence, 1991) but since post thaw recovery occurred via somatic embryogenesis it is preferable to cryopreserve the more prolific, floral-derived somatic embryos. Efficiency of cacao somatic embryogenesis continues to be improved such that now, large numbers of somatic embryos can be generated from an increasing number of genotypes. Li et al. (1998) showed that all cacao genotypes tested were capable of producing primary somatic embryos albeit at variable efficiencies. The percentage of responsive cultured staminodes for instance was as low as 0.8% for 2 of the 19 genotype. Nevertheless, it was shown that any resultant somatic embryos could be used to initiate secondary somatic embryos (Maximova et al., 2002), the multiplication rates of which were far higher. Using the secondary somatic embryo protocol of Maximova et al (2002), an encapsulation-dehydration system was developed which, without optimization on a per genotype basis, gave at least 25% recovery for each of the genotypes tested (Fang et al. 2004). A new, less labour intensive approach that utilizes the same secondary somatic embryos but with a high concentration sucrose pre-culture and the now widely used Plant Vitrification Solution 2 (PVS2) has proved to be at least as genotype independent as the previous approach, and is now being used to cryopreserve frequently requested clones at the University of Reading's ICQC,R (Adu-Gyamfi 2011): to date 12 such clones have been cryopreserved and it is the aim to back-up 10% of the ICQC,R collection within the next three years. Microsatellite analysis has shown that genetic fidelity was maintained in the post thaw secondary somatic embryo (SE) regenerants (Fang et al. 2009). An added benefit of the approach is that it can act as a barrier to the transmission of Cacao Swollen Shoot Virus (CSSV): very few somatic embryos initiated from CSSV-infected trees receive virions and the transmission rate is further reduced following cryopreservation. As shoot tip-based micropropagation of cacao is improved those propagules are likely to be amenable to similar vitrification approaches.

Annex 5. Partners and networks in the Global Strategy

Bioversity International

Bioversity undertakes research on agricultural biodiversity, dedicated to addressing global issues related to food security, poverty, climate change and environmental degradation. Bioversity is one of 15 centres of the Consortium of International Agricultural Research Centres (CGIAR), created in 1971, to reduce hunger and poverty, improve human nutrition and health, and protect the environment. One of Bioversity's research priorities is the conservation and availability of genetic resources contribute to research in the area of *ex situ*, *in situ* and on-farm conservation and availability of crops and their wild relatives, providing scientific leadership, coordination and facilitation of ongoing and new research and global partnerships. Bioversity manages a number of projects on cacao genetic resources to contribute to the welfare of the large number of smallholders cultivating cocoa through higher and sustainable productivity levels of good quality cocoa at lower production costs. The CFC/ICCO/Bioversity project on "Cocoa Germplasm Utilization and Conservation" focuses on the validation and distribution of promising varieties to farmers and to project partners through enhanced collaborative efforts. Use of improved cocoa planting material should make cocoa cultivation more competitive and more attractive to new generations of cocoa farmers. It should facilitate diversification of cocoa-based farming systems by reducing land, labour and cash requirements for cocoa cultivation. Bioversity also coordinates the global programme on Cocoa of Excellence and the International Cocoa Award. Bioversity provides the Secretariat for CacaoNet. www.bioversityinternational.org

Centre de coopération internationale en recherche agronomique pour le développement - CIRAD

CIRAD is a French research centre working with developing countries to tackle international agricultural and development issues. It is a targeted research organization, and bases its operations on development needs, from field to laboratory and from a local to a global scale. CIRAD works hand-in-hand with local people and the local environment, on complex, ever-changing issues: food security, ecological intensification, emerging diseases, the future of agriculture in developing countries, etc. CIRAD supports both cocoa producers and players further downstream in the supply chain, by developing scientific and technical innovations aimed at ensuring a sustainable cocoa economy. Its research centres on: (1) creating a range of more productive and/or better quality planting material, (2) developing appropriate control methods, (3) building decision support tools to establish viability thresholds for cocoa farms, depending on farm size and target markets and (4) developing tools to assist in defining and recognizing quality, by studying the determining factors and by labelling. CIRAD's scientists have been actively involved in the cacao GR effort for many years and in addition to the organization of collecting expeditions, have developed molecular approaches to diversity analysis and verification of accessions as well as marker-assisted and traditional breeding approaches. www.cirad.fr

Centre for Agriculture and Biosciences International - CABI

CABI is a not-for-profit international organization that improves people's lives by providing information and applying scientific expertise to solve problems in agriculture and the environment. CABI's objectives are to lift smallholder farmers out of poverty through reducing the lost crops to pests and diseases, improve crop quality and yield, and sell their produce for better prices, providing advice on agricultural practice to extension workers and information to researchers and policymakers that they need to develop strategies to support agriculture and the environment, and improve livelihoods. CABI supports research on cacao at CATIE in Costa Rica, and the *Instituto Nacional Autónomo de Investigaciones Agropecuarias* - INIAP in Ecuador on biological control potential for the fungal pathogens *Moniliophthora roreri* and *Moniliophthora perniciosa*, causal agents of frosty pod rot and witches' broom disease (WBD) respectively, main constraints to cocoa production in Central and South America. www.cabi.org

Centro Agronómico Tropical de Investigación y Enseñanza - CATIE

The collection at CATIE was initiated in 1944 in Turrialba, Costa Rica, as part of a strategy of the Inter-American Institute for Cooperation on Agriculture (IICA) to promote the exchange of germplasm of tropical crops. In 1978, CATIE's collection was registered by the International Board for Plant Genetic Resources IBPGR (now Bioversity International) as a global base collection and since 2004 it is under the auspices of the Food and Agriculture Organization of the United Nations (FAO) and covered by the ITPGRFA. In the nineties, CATIE with the support of the WCF and the USDA/ARS initiated a regional cacao breeding programme. The focus of the programme is selection and generation of high-yielding and disease resistant genotypes with emphasis on moniliasis (*Moniliophthora roreri*) and black pod (*Phytophthora palmivora*) diseases, two of the major biotic factors limiting cacao production in Central America and Mexico. The original source of the experimental germplasm is the CATIE International Cacao Collection (IC3), which currently comprises 1146 accessions collected, introduced or selected/bred by IICA/CATIE over the last 70 years with different genetic and geographic origin from Central America, Mexico, South America, the Caribbean, Asia, and Africa. Trinitario is the predominant group, however, there is also a significant representation of upper and lower Amazon Forasteros and to a lesser extent of Criollo types not found in other collections. The breeding programme now includes 28 field trials, where six segregating populations for molecular studies, 532 clones, and 292 hybrid families are under evaluation. Trees are evaluated monthly using parameters related to precocity, vigour, yield capacity and disease resistance. Renewed efforts to improve the genetic structure and physical conditions of the collection have been ongoing since 2001. From 2001-2005, it was completely renovated by propagating all original clones and establishing them at 2 distinct new sites, La Molina in Turrialba and La Lola on the Atlantic coast. CATIE collaborated with the United States Department of Agriculture (USDA) towards the renovation of the collection, its genetic enrichment by introducing strategic germplasm and the first effort towards its genetic rationalization. The objectives of the renovations were to curtail further losses of accession caused by soil-born fungus by re-organizing the collection, standardizing the number of plants per accession, rejuvenate the old trees and maintain replicates of each accession at different sites for security reasons. The improvement of the collection is a priority and the further reorganization in order to improve the accuracy and efficiency of maintaining this collection. www.catie.ac.cr

Cocoa Producers Alliance - COPAL

COPAL is an intergovernmental organization instituted in January 1962. The founding members are Ghana, Nigeria, Brazil, Côte d'Ivoire, and Cameroon. COPAL is guided by the Abidjan Charter. COPAL's objectives are to: (1) Exchange technical and scientific information, (2) Discuss problems of mutual interest and to advance social and economic relations between producers, (3) Ensure adequate supplies to the market at remunerative prices and (4) Promote the expansion of consumption. COPAL's International Cocoa Research Conferences have provided the opportunity to raise awareness of cacao genetic resources issues, to launch the CacaoNet initiative and subsequently, for CacaoNet's steering committee and working groups to meet. www.copal-cpa.org

Cocoa Research Association Ltd. - CRA Ltd.

CRA Ltd is a UK-based organization managing scientific cocoa research on behalf of Kraft Foods, Mars and the London Cocoa Trade (NYSE Liffe). Cocoa Research Association Ltd. manages a portfolio of projects focusing on research capable of benefiting cocoa growing throughout the world. The CRA Ltd. research programme is closely linked to those of its sister organizations Cocoa Research (UK) Ltd and the Ghana Cocoa Growing Research Association Ltd (GCGRA Ltd). The chocolate industry in the UK has had a long involvement in research to support the cocoa GR and breeding effort and has been a major contributor to key resources such as CRU/UWI, ICQC,R and ICGD for many decades. www.cocoaresearch.org.uk

Cocoa Research Unit of the University of the West Indies - CRU/UWI

CRU/UWI maintains the International Cocoa Genebank, Trinidad (ICG,T) established in 1982, by consolidating diverse earlier collections of cacao from several sites in Trinidad which included accessions from other national collections and from numerous missions to collect primary germplasm from the centre of diversity of cacao. A main source of original material for the ICG,T was Marper Farm, established by F.J. Pound following his expeditions to the upper Amazon from 1937 to 1942. The trees at Marper though now old, have survived periods of neglect to remain as an important anchor in confirming the identity of clones in the ICG,T and in replacing material which has proved difficult to establish. Trees in the ICG,T were propagated as rooted cuttings using budwood from the original trees and, by 1994 over 2000 accessions had been planted. Additional clones are added as they become available. The ICG,T genebank now contains one of the most diverse collections of cacao germplasm and consists now of 2400 accessions, representing the major groups of cacao (Forastero, Criollo, Trinitario and Refractario) as well as related species of *Theobroma*. About 40% of the accessions are in the Forastero group, 40% in the Refractario group, 10% in the Trinitario group and the remainder either Criollo, hybrids or unclassified. There is a constant introduction of new material to the ICG,T, either from collection expeditions to obtain primary germplasm, or from exchanges with other countries. Recent collections of primary germplasm (still to be introduced to the ICG,T) aim to increase the representation of the Criollo group. Selected cacao accessions with desirable agronomic traits are distributed to cocoa-producing countries via intermediate quarantine at the University of Reading, UK. In addition, some accessions are used in pre-breeding programmes to accumulate desirable genes especially for resistance to Black Pod and Witches' Broom diseases The main objective of such programmes is to produce enhanced germplasm that will introduce resistance genes to conventional breeding programmes in various cocoa-producing countries throughout the world. The work of CRU/UWI is supported financially in part by CRA Ltd, the Dutch Ministry of Agriculture, Nature and Food Quality or Ministerie van Landbouw, Natuur en Voedselkwaliteit, The Netherlands (LNV) and the Ministry of Food Production, Land and Marine Affairs (MFPLMA), Trinidad and Tobago. http://sta.uwi.edu/cru/

Common Fund for Commodities - CFC

CFC is an inter-governmental financial institution established within the framework of the United Nations. The Fund’s specific mandate is to support developing countries that are commodity-dependent to improve and diversify commodities’ production and trade. The Common Fund finances projects that typically have a market development and poverty alleviation orientation. Its multi-country dimension and approach places a high premium on the development of regional commodities-based economies, through a variety of project initiatives that seek to enhance the capacity of commodity producers and exporters to participate fully in global trade. CFC, with co-funding from participating institutions and industry, supported two consecutive projects (1998-2010) on cocoa germplasm utilization and conservation, which involved fourteen institutes in cocoa producing and consuming countries. www.common-fund.org

European Industry Cocoa Research Outreach Group

CAOBISCO, ECA and FCC have recently established the European Industry Cocoa Research Outreach Group to encourage cooperation in engaging with and supporting research activities which advance our knowledge on how to make cocoa production safer, improve quality and enhance productivity. The goal of more sustainable cocoa production is clearly an important area of collaboration for the whole cocoa industry and there are many opportunities for pre-competitive research and other activities which will benefit all those involved in the cocoa chain from farmers to consumers, today and into the future. The conservation and exploitation of cacao genetic resources to breed new and improved varieties and the subsequent distribution of these varieties to farmers is already recognised as a key component of sustainable cocoa production. Activities in this area are already being supported by several European companies and associations. The group seeks to improve coordination in these activities, to cooperate with research groups and to liaise with other industry and public organizations with a view to attracting funding and steering research towards issues which affect our industry.

The Association of the Chocolate, Biscuits and Confectionery Industries of Europe (CAOBISCO), through its national associations, represents 2000+ companies across these three product categories. In terms of raw materials usage we represent over 50% of world cocoa consumption, 30% of EU sugar consumption and are the major users of dairy and cereals. CAOBISCO industries are involved at all levels and with many stakeholders in working towards a sustainable cocoa economy. Our commitment covers the three pillars of sustainable development, economic, environmental and social. www.caobisco.com

The European Cocoa Association (ECA) is a trade association representing the European cocoa sector and regrouping the major companies involved in the cocoa bean trade and processing, in warehousing and related logistical activities. Together, ECA Members represent over two-thirds of Europe's cocoa beans grinding, half of Europe's industrial chocolate production and 40 % of the world production of cocoa liquor, butter and powder. On behalf of its members, ECA monitors and reports on development impacting the cocoa sector, both at regulatory and scientific levels. In addition, ECA is actively engaged in European and International fora related to the industry's contribution to a sustainable cocoa economy. www.eurococoa.com

The Federation of Cocoa Commerce Limited (FCC) is UK based and represents some 170 members engaged in the international cocoa sector. This diverse membership includes organizations and companies from cocoa producing countries, the cocoa processing and chocolate industry, cocoa trade, logistics providers, banks, brokers, insurance and others. FCC activities are focused around the cocoa supply chain being an international contract authority. We support this cocoa contract with arbitration services and a number of other initiatives to enhance integrity in the cocoa supply chain. www.cocoafederation.com

The Global Cacao Genetic Resources Network - CacaoNet

The creation of a network was proposed in 2005 to optimize the conservation and use of cacao genetic resources worldwide for the benefit of breeders, researchers and farmers. CacaoNet was officially launched at the COPAL 15th International Cocoa Research Conference in San José, Costa Rica, in October 2006. CacaoNet's overall goal is to optimize the conservation and use of cacao genetic resources, as the foundation of a sustainable cocoa economy (from farmers through research to consumers), by coordinating and strengthening the conservation and related research efforts of a worldwide network of public and private sector stakeholders. Financial and in-kind support has been contributed from a number of organizations including CRA Ltd, Mars, USDA/ARS, WCF, Bioversity International and COPAL which has permitted the CacaoNet steering committee and working groups to meet, and the coordination of the network. CacaoNet is indebted to the research institutes and organizations who have allowed their staff to participate in the network and to the individuals who have contributed their valuable time and expertise. www.cacaonet.org

Global Crop Diversity Trust

The Global Crop Diversity Trust (the Trust) was established under international law organization in October 2004, founded by FAO and Bioversity International, acting on behalf of the Consultative Group on International Agricultural Research (CGIAR). The Trust is an endowment fund for *ex situ* collections of Annex 1 crops (selected on the basis of their contribution to food security), and the collections that fall under Article 15. Cacao is included in the Article 15 under which IC3 (CATIE) and ICG,T (CRU/UWI) fall. The Trust may offer a route to manage funds designated for cacao conservation. www.croptrust.org

Government of the Netherlands

The Government of the Netherlands (Ministry of Economic Affairs, Agriculture and Innovation) supported twenty-two projects in the cocoa and chocolate manufacturing sector aimed at improving the sustainable development of the sector. These projects started in the period 2004 – 2007 and most have now been completed. The projects were implemented by various Dutch and international organizations and covered research and development activities, information supplies, training, education and/or technical assistance. Several of the projects were focussed on the genetic improvement and availability of cocoa planting material and these included projects to Safeguard the ICG,T, to improve the energy efficiency of the ICQC,R, to use molecular techniques to gain understanding of the genotype x environment effect and to initiate a new breeding programme in Ghana. The Dutch Government is now supporting the Sustainable Trade Initiative (IDH) which aims to improve the sustainability of international supply chains. IDH launched the Cocoa Productivity and Quality Programme Facility (CPQP) in January 2012. CPQP brings major players in the cocoa sector together to co-fund programmes to mainstream innovations on effective farmer support and improved production to assist smallholder farmers move out of poverty and make the transition to running viable businesses for sustainable cocoa production. www.idhsustainabletrade.com/CPQP

International Cocoa Organization - ICCO

ICCO was established in 1973 under the auspices of the United Nations to administer the provisions of the International Cocoa Agreement (ICA) concluded amongst the Governments of cocoa-producing and cocoa-consuming countries at conferences convened by the United Nations. The ICCO aims to strengthen the global cocoa sector, support its sustainable development and increase the benefits to all stakeholders. The ICCO is co-operating with other institutions and the Common Fund for Commodities on the development and implementation of projects aimed at improving the structural conditions of cocoa markets and enhancing long-term competitiveness and prospects in the world cocoa economy, including two major projects which focussed on the conservation and utilization of cacao genetic resources. www.icco.org

International Cocoa Quarantine Centre - ICQC,R

The ICQC,R, established in 1985 at the University of Reading, UK, holds approximately 450 cacao accessions (350 clones available for exchange and a further 100 undergoing quarantine). The ICQC,R is funded by the Cocoa Research Association Ltd (CRA Ltd) and the United States Department of Agriculture (USDA) with additional funding from the Common Fund for Commodities (CFC). The ICQC,R provides pest and disease free material both for use within the University and internationally. The current quarantine procedure involves a two year visual observation period to check for latent viral infections supervised by an experienced virologist. The facilities, plus laboratories fitted with the latest equipment for molecular biology and *in vitro* culture, enable pioneering research in cocoa physiology, pathology, genetic fingerprinting and tissue culture. Research is underway to improve and accelerate the quarantine process using new technologies. Since 1985 many cacao clones have passed through the ICQC,R facility and many shipments made. Most of these have been received from the International Genebanks in Trinidad (ICG,T) and Costa Rica (CATIE), but material has also been received from the wild and national collections. In addition, ICQC,R cryopreserves frequently requested clones. To date 12 such clones have been cryopreserved and it is the aim to back-up 10% of the ICQC,R collection within the next three years. www.icgd.reading.ac.uk/quarantine.php

International Group for Genetic Improvement of Cocoa – INGENIC

INGENIC was created in 1994 to promote the exchange of information and international collaboration on cocoa genetics and improvement of cocoa planting materials. It organizes international workshops on cacao genetics and breeding topics, and newsletters and internet discussion groups to allow members to share their results. INGENIC membership includes over 300 members, representing 35 developing and developed countries around the world. INGENIC has helped to raise awareness of the CacaoNet initiative, particularly through a survey that it conducted amongst its members in 2007 and at its workshops. INGENIC is supported by the institutes which have allowed their staff to form the secretariat of INGENIC (Bioversity/CIRAD, CRA, CRIG, CRU/UWI, MCB, Penn State University, UESC) and financial support from various public and private sector sources which have included CRA, Mars, *Stiftung der Deutschen Kakao- und Schokoladenwirtschaft*, and USDA/ARS. INGENIC is grateful to the support of COPAL, and its partner organizations in host countries, for allowing the INGENIC Workshops to be coordinated with the International Cocoa Research Conferences. http://ingenic.cas.psu.edu

International Institute for Tropical Agriculture – IITA

An"African Cacao Breeders' Working Group (ACBWG)" is already in place with IITA as a technical partner to coordinate and build support for regional efforts in cacao genetic resources and breeding programmes within West and Central Africa. The ACBWG has carried out SSR genotyping to understand the diversity of the cocoa germplasm in farmers' fields and research stations in four producing countries in West Africa such as Nigeria, Ghana, Cote d'Ivoire and Cameroon. The results demonstrated the narrow genetic base in farmers' fields and the immediate need for diversifying with inclusion of improved planting materials from breeders' collection to combat the loss through prevailing and emerging pests and diseases in the region. Presently, ACBWG is involved in a regionally coordinated research programme, African Cocoa Initiative, to support sustainable productivity growth and improved food security on diversified cocoa farms in West and Central Africa. Accessing improved planting material is a problem for farmers in most areas, especially those distant to existing seed gardens. This issue which is common to the subregion offers wide scope for sharing and collaboration on alternative decentralized seed/budwood garden approaches. These include somatic embryogenesis to produce clonal planting materials, molecular technologies to confirm the parentage of seed garden hybrids and to ensure disease-free planting materials. Research on seed storage methods and other methods of altering the seasonal availability of hybrid seed to better match farmers' seasonal demand for planting seed at the start of the rains in March/April could generate a high return. IITA has facilities for tissue culture/micropropagation in its Genetic Resource Center, a well established Germplasm Health Unit, and a well equipped Bioscience Center, which could handle the regional requirement by providing technical backstopping or safe duplication of regional genetic materials. www.iita.org

International Treaty on Plant Genetic Resources for Food and Agriculture - ITPGRFA

The ITPGRFA came into force on 29 June 2004. Its objectives are the conservation and sustainable use of all plant genetic resources for food and agriculture and the fair and equitable sharing of benefits that arise from their use. The core of the Treaty is its Multilateral System of Access and Benefit-Sharing (MLS of ABS), which ensures continuous availability of important genetic resources for research and plant breeding, whilst providing for the equitable sharing of benefits, including monetary benefits that are derived from commercialization. Cacao is not specifically listed in the Annex 1 of the MLS but the two international collections at CATIE and CRU/UWI however signed agreements with the Treaty and their collections are covered under the Article 15. www.planttreaty.org

Kraft Foods

Kraft Foods is the world's biggest chocolate company and uses around 11% if the world's total cocoa crop. Cadbury, one of Kraft's biggest brands has been actively influencing the future of cocoa and the communities that grow it for several years. In 2008, Cadbury launched the Cadbury Cocoa Partnership to help secure the economic, social and environmental sustainability of cocoa. Through the Cocoa Partnership Kraft has committed 45 million pounds Sterling (approximately $70 million) to invest in cocoa farming in Ghana, India, Southeast Asia and the Caribbean over 10 years. The programme is already operating in 100 Ghanaian communities, with plans to double in size by year-end 2012. The Partnership has forged successful alliances with The Ghana Cocoa Board and the fair trade co-op Kuapa Kokoo. The Cocoa Partnership's success depends on the collaborations that are established with other companies, governments and NGOs. The challenges facing today's cocoa farmer cannot be solved by any one company or organization but only by working together, public and private sectors along with farmers and civil society, to make the difference. The company has recently extended its commitment to sustainable cocoa by incorporating a research track into the programme, recognising the need to increased cocoa productivity through improved planting material and farming practice. www.kraftfoodscompany.com/home/index.aspx

Mars Incorporated

Mars is one of the world's major food manufacturers who's long-term business depends on a sustainable supply of high-quality cocoa. Mars' approach is to build a public/private network that helps promote and support these elements around the world in order to address the major challenges facing farmers and the industry. Mars is leading the way in cocoa research to help fill the gap left by years of underinvestment, especially in plant genetics and breeding, pest and disease control and post-harvest practices. They share relevant findings so they benefit the cocoa industry as a whole and reach farmers quickly and effectively. Mars fund and lead innovative programmes that will advance the industry's understanding of how to increase the quality and performance of cocoa plants and better control pests and disease. Its primary goals to advance global cocoa research are: (1) to increase collaboration between cocoa-producing and cocoa-consuming regions through stronger regional links and increased contact, (2) to create an effective common agenda across the industry to prioritize key issues within genetics, quality and agronomy, (3) to increase funding available to cocoa researchers and (4) to enhance the publication and dissemination of cocoa research. Mars is working on sequencing and annotating the cocoa genome in a partnership that includes IBM and the U.S. Department of Agriculture (USDA). In 2010, the consortium unveiled the initial results of its programme into the public domain, where they are permanently accessible via the Cocoa Genome Database. By making the results available to the industry and scientific community, the project partners are helping accelerate future cocoa research and the application of knowledge on the ground. Through its Sustainable Cocoa Initiative, Mars Chocolate invests tens of millions of dollars annually in cocoa-focused agricultural research, technology transfer programmes to increase yields and income for farmers in Africa and Asia, and certification programmes to promote acceptable conditions for farmers in its supply chain. Mars's guiding principle is to put 'Farmers First,' by prioritizing activities through which farmers will achieve higher yields and larger incomes that will in turn support broader social development and better environmental protection. Mars supports the work of many partners including Bioversity, in improving the accessibility of farmers to planting materials and methodology. Mars supported the development of this Global Strategy and is an active member in CacaoNet and is current chairing the Network. www.mars.com/global/brands/cocoa-sustainability-home.aspx

Nestlé

Nestlé is a leading chocolate manufacturer and a major user of cocoa. The group, headquartered in Switzerland, has a global footprint and is processing cocoa and cocoa products from all major producing origins. One of the group's main concerns is the sustainability of cocoa production and the long-term availability of good quality cocoa. In this context, the Group launched in 2009 a major initiative, the Nestlé Cocoa Plan, which aims at improving the lives of cocoa farmers and their communities, to ensure that cocoa production will remain an attractive activity for farmers in the long run. The Nestlé Cocoa Plan puts a major emphasis on technical assistance to small planters, to increase farm productivity; in particular, Nestlé aims to provide better trees to growers to help them improve yields and reduce disease. Nestlé has for many years been involved in cocoa research. One of the major concentrations of Nestlé's cocoa research is on tree selection and breeding. The Company has a modern platform of marker-assisted selection, which it uses, in collaboration with national research institutes, to accelerate the release of improved cocoa varieties to farmers in producing countries. In relation with this programme and the Cocoa Plan, Nestlé believes it is of the outmost importance to preserve cocoa genetic resources and promote their circulation and use. This is why strength of Nestlé's cocoa research is cryopreservation, a technique of high relevance to complement field collections. Being aware that propagation is often a bottleneck, Nestlé has become a leader in cocoa tree propagation techniques. In particular, the Company has pioneered somatic embryogenesis (SE) for cocoa, a technique that has now been used towards the production of millions of trees around the world. Nestlé has transferred the technology to institutes in several producing countries and is putting a major effort in applying it through dedicated propagation structures for the distribution of productive varieties to farmers in Africa, Asia and the Americas. The ultimate objectives of our cocoa research are to serve the farmers, through more productive, better farming in compliance with our supplier code, to delight the consumer, through great tasting products made of the best quality cocoas and to improve the environment through a use of the land that is respectful of nature and farming communities. More information on the Nestlé Cocoa Plan at: www.nestlecocoaplan.com

United States Department of Agriculture - USDA

USDA and the Agricultural Research Service (ARS) are currently supporting over 30 projects related to cacao. One of them is the Support of CacaoNet and INGENIC activities since 2009. The objectives for this joint Bioversity /USDA/ARS project are to collaborate with partners from the private and public sectors to encourage cacao genetic resource collections and cacao breeding programmes to commit germplasm, breeding lines and capacity, information, in-kind resources, and institutional support to fostering the global capacity to conserve, genetically-improve, and sustainably use cacao genetic resources. In addition USDA/ARS provides support to a number of other projects related to cacao GR including work at CATIE, CRU/UWI, ICQC,R and its own genetic diversity/genomics activities at Beltsville Agricultural Research Center, Sub-Tropical Horticulture Research Station, Miami and Tropical Agricultural Station in Puerto Rico. www.ars.usda.gov

University of Reading, UK

The University of Reading has close links with the cocoa industry in both the UK and the producing countries and is involved in various international cocoa projects. It serves an important function as the only international quarantine centre (ICQC,R described below) for safe transfer of genetic cacao material throughout the world. The University of Reading also manages the International Cocoa Germplasm Database (ICGD) (described in Section 2.4.2 on behalf of the cacao community which serves as an important source of germplasm information. www.reading.ac.uk/biologicalsciences/

World Agroforestry Centre - ICRAF

In collaboration with MARS and national stakeholders, the World Agroforestry Centre (ICRAF) implements the Vision for Change project in Cote d'Ivoire aimed at revitalizing the cocoa sector through the delivery of improved productivity package, including the supply of improved planting material to farmers. Clonal testing and selection, clonal propagation via clonal gardens and somatic embryogenesis, pests and diseases management as well as soil fertility management and crop diversification are the major interventions of the project to sustain productivity. Agronomic performances of selected and introduced clones are evaluated at multi-location trials. One major innovation proposed by the project is the grafting of budwood from an improved, selected variety onto the trunk or chupon of a mature unimproved tree. Clonal gardens are created at strategic locations to build the capacity to produce budwoods. Community-based participatory research approach is used to involve farmers in the process of selection and multiplication of good planting material for the regeneration of their ageing Cacao tree. Clonal propagation of superior germplasm via tissue culture (induction of somatic embryogenesis in cocoa explants and maturation of these embryos into plantlets) is also being explored. It is anticipated an increased capacity to supply and promote improved planting material that are high yielding, resistant to pest and diseases while maintaining the "West African" flavour. Farmers' awareness on the need to regenerate their farms with superior cacao planting material and other good agricultural practices will be enhanced. www.icraf.org

World Cocoa Foundation - WCF

WCF supports cacao farmers and their families worldwide. WCF members comprise a large part of the cocoa and chocolate private sector, and their programmes raise farmer incomes, encourage responsible, sustainable cacao farming and strengthen communities. WCF promotes a sustainable cocoa economy through economic and social development and environmental stewardship in cocoa-growing communities. WCF achieves its goals by: (1) building partnerships with cocoa farmers, origin governments and agricultural, development, and environmental organizations, (2) working with international donors to support effective programmes, (3) supporting and applying demand-led research that improves crop yield and quality and (4) supporting training and education that improves the health, safety and well-being of cocoa farming families. As well as direct support for the genetic resources effort including projects at CATIE and CRU/UWI, WCF has also invited presentations on Cacaonet/GR at its partnership meetings and provided meeting facilities for CacaoNet's Steering Committee and working groups. www.worldcocoafoundation.org

Annex 6. Description of the agreed methodology to select accessions based on allelic diversity

We employ two traditional core selection methods that use grouping and selection of an optimum set of accessions followed by a further iteration designed to reduce the redundancy of the core selection (van Raamsdonk & Wijnker, 2000; van Treuren et al., 2008; van Treuren et al., 2009). The method is illustrated by way of reference to a large public dataset of simple sequence repeat (SSR) information (microsatellite markers). However, the method is not limited to the analysis of molecular genetics data but can combine both discrete categorical and continuous variable data classes. Importantly, initial population differentiation and selection of representative subsets from a population need not make use of only a single data type across the whole cacao resource; a consistent data type is only required for the final selection of the non-redundant core collection. However, for clarity and due to the incomplete nature and inconsistencies in data entry format for morphological, physiological, and agronomically valued information in this example only molecular data has been used. The primary dataset used as an example to demonstrate the utility of this model made use of a public dataset first published by Motamayor et al. in 2008 (http://www.ars.usda.gov/Research/docs.htm?docid=16432). Our method follows an iterative approach employing a three step procedure; first the genetic resource is stratified into distinct groups; second, an optimum set is selected from within each group; third, the combined selections from each group are combined and subject to a further round of selection to reduce the redundancy within the sum of the selections from the representative groups.

Population definition

As a stratification method, the software tool STRUCTURE 2.3 (Pritchard) was used to differentiate accessions into population groups. We employed 200,000 burn-in iterations and 200,000 iterations under an admixture model. Similar run parameters have been used elsewhere for the analysis of *cacao* population structure (Motamayor et al., 2008).

Minimum core size and optimized composition selected for maximum allelic richness

A method of maximizing allelic richness is employed to select a subset of accessions of minimal size by replacement based on the number of represented classes of marker variables for the number of accessions within the sample (Gouesnard et al. 2001). We employed the Shannon index as a measure of allelic diversity:

$$I_{Shannon,j} = - \Sigma(p_{ij} \ln p_{ij})$$

where p_{ij} represents the i^{th} class frequency of the j^{th} variable.

This sampling strategy, based on allele frequency, favours core collections with fairly distributed allelic classes, rather than a biased selection of rare alleles. This method has previously been shown to provide the optimum solution for selection of core collections utilizing SSR data (Escribano et al., 2008). For comparison we plotted sample scores for an equal number of randomly composed core sets of equal size. We employed 20 replicate runs and 10,000 iterations within each replicate for each population group.

Once the minimal sample size required to contain maximum allelic richness has been determined for each population group, core selections of this size are constructed by replacement to identify the specific accessions contained within the optimum set. We employed 100 replicate runs and 1000 iterations within each replicate ensure adequate sampling given the size of each group and the magnitude of the selection to be made from it in each case.

Annex 7. Membership of accessions for the GSCC based on allelic diversity

The list below includes a total of 261 accessions.

NOTE: This draft list is based exclusively on DNA derived genetic data and makes no use of agronomical or morphological trait information. Population groupings employ the same geographically derived naming system employed by Motamayor et al. 2008.

Accession	Population	Accession	Population	Accession	Population
LCTEEN 302	Amelonado	U 56	Contamana	TC 9	Criollo
MA 11	Amelonado	U 57	Contamana	B 48	Criollo
LCTEEN 26	Amelonado	TAP 3	Contamana	CHA 20	Criollo
MA 14 PL9	Amelonado	U 39	Contamana	CHA 18	Criollo
CAB 0733	Amelonado	CAB 185	Contamana	CA S5	Criollo
SPEC 41/6 18	Amelonado	U 68	Contamana	SJU 1	Criollo
CAB 36	Amelonado	CAB 186	Contamana	STA MARIA 2	Criollo
BE 8	Amelonado	U 36	Contamana	LIB 2	Criollo
MA 12	Amelonado	SCA 5	Contamana	LCTEEN 134	Curaray
YAL 5A	Amelonado	U 5	Contamana	LCTEEN 334	Curaray
CJ 5	Amelonado	U 2	Contamana	LCTEEN 390	Curaray
BE 2	Amelonado	UCA 1	Contamana	LCTEEN 121	Curaray
U 59	Contamana	CAB 188	Contamana	LCTEEN 123	Curaray
CAB 183	Contamana	U 58	Contamana	LCTEEN 386	Curaray
U 66	Contamana	CAB 184	Contamana	LCTEEN 434	Curaray
U 49	Contamana	U 4	Contamana	LCTEEN 329	Curaray
CAB 190	Contamana	U 70	Contamana	LCTEEN 94	Curaray
U 28	Contamana	CRIOLLO 13	Criollo	LCTEEN 403	Curaray
U 38	Contamana	PER 2	Criollo	CURIS	Curaray
U 15	Contamana	CHA 13	Criollo	LCTEEN 261/S 4	Curaray
U 37	Contamana	TC 3	Criollo	LCTEEN 281	Curaray
U 31	Contamana	TC 1	Criollo	LCTEEN 87	Curaray

Accession	Population	Accession	Population	Accession	Population
LCTEEN 432	Curaray	ELP 20 A	Guiana	CAB 17	Marañón
LCTEEN 389	Curaray	ELP 32 A	Guiana	CAB 19	Marañón
LCTEEN 188	Curaray	KER 11 1 L	Guiana	PA 52	Marañón
LCTEEN 234	Curaray	GU 134B	Guiana	CAB 0224	Marañón
LCTEEN 257	Curaray	CAB 0517	Iquitos	CAB 0776	Marañón
LCTEEN 189	Curaray	U 10	Iquitos	PA 135	Marañón
LCTEEN 219	Curaray	SPEC 54/1	Iquitos	PA 18	Marañón
LCTEEN 193	Curaray	CAB 0330	Iquitos	PA 202	Marañón
LCTEEN 80	Curaray	CAB 0367	Iquitos	CAB 23	Marañón
LCTEEN 122	Curaray	CAB 0531	Iquitos	PA 294	Marañón
LCTEEN 180	Curaray	AMAZ 10	Iquitos	CAB 0219	Marañón
NAP 25	Curaray	NA 68	Iquitos	PA 139	Marañón
LCTEEN 195	Curaray	AMAZ15/15[CHA]	Iquitos	PA 1	Marañón
LCTEEN 325	Curaray	CAB 0516	Iquitos	CAB 0251	Marañón
LCTEEN 255	Curaray	COCA3370/5[CHA]	Iquitos	CAB 0777	Marañón
LCTEEN 57	Curaray	AMAZ 2	Iquitos	PA 187	Marañón
LCTEEN 152	Curaray	NA 268	Iquitos	CAB 0440	Marañón
LCTEEN 421	Curaray	CAB 0527	Iquitos	PA 4	Marañón
LCTEEN 333	Curaray	CAB 0328	Iquitos	PA 179	Marañón
NAP 3	Curaray	C.Sul 1	Iquitos	PA 82	Marañón
LCTEEN 227	Curaray	AMAZ 13	Iquitos	CAB 0764	Marañón
LCTEEN 60	Curaray	AMAZ 5/2 [CHA]	Iquitos	CAB 0466	Marañón
KER 1 L	Guiana	AMAZ 15 [CHA]	Iquitos	PA 88	Marañón
CJ 4	Guiana	NA 409	Iquitos	CAB 0422	Marañón
CJ 2	Guiana	CAB 0331	Iquitos	CAB 0458	Marañón
GU 156B	Guiana	CAB 0324	Iquitos	CAB 0459	Marañón
KER 3	Guiana	PA 98	Marañón	CAB 21	Marañón
B7 B3	Guiana	PA 175	Marañón	PA 30	Marañón

Accession	Population	Accession	Population	Accession	Population
PA 188	Marañón	POUND 10/B	Nanay	CAB 0369	Purús
CAB 0452	Marañón	NA 79	Nanay	CAB 197	Purús
PA 165	Marañón	NA 702	Nanay	CAB 200	Purús
CAB 0783	Marañón	NA 435	Nanay	CAB 0368	Purús
PA 310	Marañón	NA 753	Nanay	EBC 138	Purús
CAB 0749	Marañón	NA 283	Nanay	CAB 154	Purús
LCTEEN 73	Nacional	NA 841	Nanay	LCTEEN 368	Purús
LCTEEN 91	Nacional	NA 92	Nanay	EBC 121	Purús
MO 90	Nacional	NA 279	Nanay	CAB 0344	Purús
LCTEEN 312	Nacional	EBC 114	Purús	EBC 136	Purús
LasBrisas 13 13	Nacional	CAB 67	Purús	CAB 193	Purús
MO 122	Nacional	CAB 0514	Purús	CAB 194	Purús
TAP 8	Nacional	CAB 0484	Purús	CAB 0341	Purús
NA 712	Nacional	C.Sul 5	Purús	LCTEEN 371	Purús
TAP 5	Nacional	CAB 198	Purús	CAB 150	Purús
MO 84	Nacional	CAB 0495	Purús	CAB 0475	Purús
MO 125	Nacional	CAB 148	Purús	LCTEEN 406	Purús
UCA 3	Nacional	EBC 142	Purús	CAB 0357	Purús
MO 20	Nacional	CAB 70	Purús	LCTEEN 412	Purús
U 22	Nacional	CAB 77 PL5	Purús	LCTEEN 415	Purús
NA 672	Nanay	RB 40	Purús	LCTEEN 409	Purús
NA 406	Nanay	LCTEEN 369	Purús	CAB 152	Purús
NA 768	Nanay	CAB 0334	Purús	CAB 0342	Purús
NA 326	Nanay	CAB 128	Purús	CAB 0211	Purús
NA 227	Nanay	C.Sul 9	Purús	CAB 181	Purús
NA 232	Nanay	CAB 130	Purús	CAB 0236	Purús
U 9	Nanay	CAB 195	Purús	CAB 0213	Purús
NA 206	Nanay	CAB 151	Purús	SIC 961	Amelonado

Accession	Population
VILLANO 2 [CHA]	Curaray
NA 249	Nanay
FSC 7	Amelondo
TAP 2	Nacional
SIC 801	Amelonado
BOB 8 [CHA]	Nacional
TAP 1	Nacional
NA 950	Nanay
AGU 8	Curaray
IMC 27	Iquitos
NA 254	Nanay
PA 289	Maranon
NA 3	Nanay
NA 12	Nanay
WILD	#N/A
NA 337	Nanay
ICS 100	Trinitario
ICS 80	Trinitario
ICS 46	Trinitario
ICS 35	Trinitario
ICS 86	Trinitario
ICS 10	Trinitario
ICS 14	Trinitario
ICS 95	Trinitario
ICS 40	Trinitario
ICS 65	Trinitario
ICS 71	Trinitario

Annex 8. Proposal to the CGIAR Fund Council, submitted in 2011 by the CGIAR Consortium Board of Trustees, for financial support to the CGIAR center genebanks

Note: Below are extracts of relevant sections used in the costing exercise for the Global Strategy.

2.3 Boundaries: what's in and what's out - page 22

A typical CGIAR Centre genebank operation includes many activities that, while important or even essential, have not been costed in this study because they do not directly involve the conservation and distribution of existing accessions and the information about them. The specific functions covered, and the way they have been addressed in the study, are described in detail in Annex 4.

In brief they include:

- Acquisition: bringing new material into the collection – at an annual rate of 1% per year of the 2010 total accessions (i.e. not compounded), plus known new acquisitions resulting from the Regeneration Project;
- Characterization: only essential passport and characterization data have been included, primarily those used for accession identification purposes. Molecular characterization was largely excluded except for clonal crops for which the identification and elimination of unwanted duplicates is important;
- Safety duplication, including, where appropriate, the cost of preparing material to be sent to the Svalbard Global Seed Vault;
- Preservation of vegetatively-propagated crops; *in vitro* conservation, cryopreservation, field genebanks, collections of lyophilized leaves, true seed, DNA collections and herbaria, as appropriate,
- Medium- and long-term seed storage;
- Regeneration;
- Distribution, including compliance with international agreements and regulations;
- Information management for genebank operations and for making information about the collections widely available electronically;
- General management, including professional staff cost.

Important genebank functions that have not been considered in this study include:

- Collecting;
- Molecular characterization for the identification of duplicates (except in the case of some collections of vegetatively-propagated crops that are very expensive to maintain);

- Evaluating the germplasm for important traits;
- Pre-breeding;
- Training;
- Research on conservation methodology, reproductive biology, taxonomy, etc.;
- Networking and providing international leadership and facilitation; and
- Public awareness, attendance at conferences, visitors services etc.

In the course of this study, the genebank managers were asked to carefully cost only the relevant activities, and these were discussed where appropriate during the interview and clarification stage. Nevertheless, it is possible that there are some grey areas, or simply that some costs have been inadvertently included that should not have been. The consultants are confident, however, that the impact of any such data errors is minor.

2.4 US$ cost per accession per year, for comparison

In order to be able to compare costs across the system, the cost of each relevant activity was calculated in terms of the annualized cost per accession (taking into account the total cost of the activity and the number of accession involved in the year under study, together with the average frequency of the event per accession over years). This annualized accession cost was multiplied by the total number of accessions in the collection to give an overall annual cost of maintaining and distributing the collection. To this was added the annualized capital costs associated with the collection.

The frequency of operation was set largely according to best practice in the individual genebank. Acquisition and distribution rates, however, were influenced by the peculiarities of the year under study. In general, rates of distribution vary widely across Centres and across years within Centres. The collections were, therefore, divided into three subsets according to the quantity of materials that were distributed in 2009, and the frequency of distribution was standardized for each subset (at an average frequency of distribution of 2, 7 or 20 years respectively, per accession). Acquisition rates were also standardized at a rate of 1% of the total 2009 accessions added per year.

The per-accession costs of maintenance and distribution vary considerably depending on the crop, Centre and other factors. Nevertheless, calculating the cost on this basis means there is a simple relationship between the number of accessions and the total cost of the genebank – the "bottom line" objective of the study. It is easy to see, for example, that some genebanks in the CGIAR have relatively few accessions, but may have a relatively high total cost, for perfectly valid reasons, and vice-versa.

2.5 One-off *vs.* recurrent costs

In order to calculate the annualized cost of an accession maintained within a collection functioning in a well-established routine two types of costs were calculated:

a) one-off costs that are only incurred once during the "life" of an accession such as acquisition (entry of a new accession into a collection), characterization (once an accession has been adequately characterized, the exercise does not have to be repeated) and introduction into cryopreservation; and

b) recurrent costs for activities that occur annually (such as maintaining the material in medium- and long-term storage – electricity costs and the like) or that occur at regular and predictable intervals (such as regeneration that may take place only once every 15 – 50 years) and that can be annualized by taking into account the number of accessions involved in any one year.

One-off costs have only been included in the annualized cost estimate for new accessions acquired at a "background" acquisition rate of 1% per year. (But, see 2.9 below).

Many collections, however, are not functioning totally routinely and require additional support in order to optimize the collection. This is particularly the case for *in vitro* collections. In addition, most collections need to deal with backlogs in regeneration, health testing, cryopreservation, etc. The costs of one-time activities such as these have not been included in the annualized costs, but some of the major instances reported to the consultants are provided in Section 4 below.

2.6 Full costs of operation: defining and handling direct and indirect costs

In calculating genebank costs, Centres were asked to ensure that full costs were computed, according to the current CGIAR policy on Full Cost Recovery. Accordingly, in addition to the direct scientific costs, the Centres included a variety of institutional direct costs such as facility use (electricity, security, maintenance, etc.), information technology costs (usually calculated as a full cost assigned to each computer), and other direct support costs. Additionally, the model required that each Centre include its indirect cost rate (overhead) that is then applied to all other components. The results generate a full cost of genebank operation, sorted by crop and by cost component. The summaries of these raw data for each Centre and each crop (sometimes an aggregate of several related species) are given in Table 2.1 above.

We add a word of caution here although the CGIAR system has developed a methodology for calculating full costs (Financial Guidelines Series No. 5) it is a reality that the pace of adoption and methodological refinement still varies somewhat between Centres. Accordingly, if these costs were to be re-calculated in, say, three years, the full costs at some Centres may be slightly different (probably higher) than the current values, as their full cost recovery methodologies are finalized. Having stated this, the consultants are confident that the results of the study are valid with only minor variances between Centres" results due to internal costing methodologies.

2.7 Capital costs

As the objective of this exercise is to determine the best estimate of current costs of maintaining the materials in a genebank and of distributing them, it is appropriate to include the costs on a "current year" basis. This is a simple matter for operational costs, as these are budgeted annually, and takes into account real-time effects of inflation and currency values. However, bringing the capital costs to the present value requires slightly more effort.

The financial model calculates the present annual value of the capital stock (infrastructure and equipment). In order to produce the annual costs of the genebank, current prices are converted to nominal prices using Consumer Price

Index information entered in the costing tool, and annualized using a discount rate requested in the information section of the tool. The discount factor is the average interest rate in the country where the genebank has their bank accounts, but in the case of the CGIAR system these accounts are usually kept in international banking centres (US, Europe, or elsewhere) and so an appropriate rate to use is an "average" interest rate for OECD countries. The discount rate is the interest rate used to find the present value of an amount to be paid or received in the future. This discount rate is used for annualizing the capital costs and also for estimating the in-perpetuity costs.

It is important to take into account that the annualized capital figure:

- Is not the same number that derives from an accounting calculation of depreciation, which simply spreads out the original cost of an item over the life of that item, and which makes no allowance for inflation or present value;
- Is not the replacement cost of the infrastructure or equipment. It is the best estimate, using classical financial calculations, of expressing the capital stock's annualized cost in present value terms. Calculating the cost of replacement of the capital stock is an entirely different exercise, and would take account of changes in technology, new unit costs, and many other factors. (However, as a mechanism for building a cash reserve – i.e. a "capital fund" – using the present value rather than the simple depreciation cost would result in faster cash accumulation).

2.8 Comparative costs

It is always tempting to compare costs of any operation between institutions – in this case the CGIAR Centres – especially for activities that seem, on the surface, to be similar in nature. For genebanks, this is especially a temptation when the same crop or group of crops is housed in different Centres. We add a strong note of caution that such comparisons can lead to incorrect conclusions about efficiency, cost-effectiveness or, especially, musings about combining collections in a single location. There are many reasons why some genebank operations are less or more expensive than others, for example:

- Nature of the collection itself – this may be the most significant single factor;
- Location of the genebank – local labour costs may vary significantly, for example, and if an operation is labour-intensive, this will affect total costs;
- Unit costs differ depending on local markets and circumstances (inflation, local currency valuation, and input costs such as electricity and materials/services, etc.);
- Size of operation – there may be economies of scale affecting total costs;
- Institutional factors such as organizational structure and scale of overall activity may affect cost recovery metrics resulting in different costs at different locations.

2.9 Increasing collection size

The calculation of annualized costs takes into account that the collections are growing. From a discussion with the genebank managers, it appears that the average annual acquisition rate across the system is about 1% of the total 2009 accessions. Although this varies considerably from year to year, and some collections are growing faster than others, this average rate has been used, non-compounded, for all of the individual collection calculations with the exception of those collections which are not expecting to receive any new acquisitions.

The growth in collections has two main consequences:

a) There are annual one-off costs associated with bringing new material into the collections; and

b) Annual costs will grow over time as the collections grow.

A particularly large influx of new material into the collections is expected over the next 1-3 years as newly regenerated materials are sent to Centres from the Regeneration Project. For the purpose of estimating the costs of introducing new material, the sum total of per accession costs for all operations (regeneration, health-testing, seed processing, cryopreservation, etc) is included, except for distribution and routine maintenance in long- and medium-term storage. In some cases where materials are being safety duplicated or originate from other genebanks, a new accession may not need to go through an entire cycle of regeneration, in which case the introduction costs here are a substantial over-estimation of actual costs.

Recognizing that new acquisitions will have a significant impact on overall future annual collection maintenance and distribution costs, the information provided for each Centre gives cost estimates based on the size of the collection at the end of 2009 (corresponding to year of the financial data) as well as estimates based on the size of the collection expected in 2015. The additional accessions resulting from the Regeneration Project have only been included in the calculation of 2015 collection sizes when these exceed the total background acquisition rate for the five years.

2.10 Contingency

Given the uncertainty surrounding some of the data, it might be wise in any overall calculation of costs to include a contingency of, say, 10% to cover such events as higher rates of acquisition of new accessions than the 1% included in the study, and moves towards generating more, and making greater use of molecular data.

3. Centre x collection cost summaries (current and 2015)

This section provides summarized information on the annual and one-off costs of maintaining and distributing the germplasm and related information for each of the main CGIAR crop collections in 2009 and 2015. The one-off costs of introducing new materials above the background acquisition rate and for reducing regeneration and other backlogs are given in Section 4.

3.2 Bioversity: Banana and Plantain

Because of the need to locate the collection in a country free from banana diseases, Bioversity International's banana and plantain (*Musa*) collection is maintained at the *Katholieke Universiteit Leuven*, Belgium in the International Transit Centre (ITC). The collection comprises approximately 1300 accessions that are maintained *in vitro*, and require sub-culturing every year and refreshing every 10 years (i.e. growing out as plants in the greenhouse, with field testing in the region of origin to check for somaclonal variation, etc.). Approximately 60% of the collection is currently cryopreserved and putting the remaining collection (plus new acquisitions) into liquid nitrogen represents a very significant "one-off" cost (see Section 4). The cost of virus indexing (mostly carried out in Australia) and, where needed, therapy is also very significant. The rationalization of operations (e.g. *in vitro* conservation and rejuvenation) may be possible once the collection is entirely cryopreserved.

Annual costs US$	**2010**	**2015**
Number of accessions	**1298**	**1412**
Annual recurring cost per accession	**652.50**	**652.50**
Total annual recurring cost of maintaining existing accessions	846,946	921,331
Annual cost of acquiring 1% additional accessions (non-compounded)	41,492	41,492
Total annual capital costs	63,456	63,456
Total Annual cost	**951,894**	**1,026,279**

3.3 CIAT: Cassava

The cassava collection at CIAT comprises some 6500 accessions, mainly of the cultivated species *Manihot esculenta* but with approximately 900 accessions of about 30 species of wild relatives. The number of wild relatives is not expected to increase significantly as long as they remain excluded from the Multilateral System of Access and Benefit Sharing under the International Treaty on Plant Genetic Resources for Food and Agriculture. There is no major overall cost differential between conserving wild and cultivated accessions and all are maintained *in vitro*. A core collection of about 10% of the total collection is cryopreserved. Work is underway to produce a robust protocol for seed production and conservation. CIAT also maintains a "bonsai" collection (small plants maintained in pots in the greenhouse) of approximately 2000 accessions as a source of tissue for DNA sampling, etc. There is no field collection of cassava at CIAT due to pest and disease problems. Only one third of the collection is safety duplicated in another location. It remains to be decided how to improve the security of the collection and which accessions should be conserved in what form. The costs of cryobanking further accessions are included as a one-off cost in Section 4.

Annual costs US$	**2010**	**2015**
Number of accessions	**6592**	**7137**
Annual recurring cost per accession	**71.88**	**71.88**
Total annual recurring cost of maintaining existing accessions	473,806	512,978
Annual cost of acquiring 1% additional accessions (non-compounded)	25,687	25,687
Total annual capital costs	102,552	102,552
Total Annual cost	**602,044**	**641,217**

3.5. CIP

3.5.1 CIP: Andean roots and tubers

The collection comprises approximately 1800 accessions of 11 species mostly held *in vitro* culture. The most important are oca (*Oxalis tuberosa;* 788 accessions), olluco (*Ullucus tuberosus;* 573 accessions), and mashua (*Tropaeolum tuberosum;* 150 accessions). The majority of accessions are also maintained in the field. Only maca (*Lepidium meyenii)*, and yam bean (*Pachyrhizus* spp.) can be maintained as seed. There are no robust cryopreservation protocols, although some work is being done on oca. As these crops are not listed in Annex 1 of the International Treaty on PGRFA, their distribution from Peru is very difficult. Thus most distribution of the collection is only within Peru.

Annual costs US$	**2010**	**2015**
Number of accessions	**1174**	**1264**
Annual recurring cost per accession	**146.50**	**146.50**
Total annual recurring cost of maintaining existing accessions	171,987	185,171
Annual cost of acquiring 1% additional accessions (non-compounded)	9,179	9,179
Total annual capital costs	16,289	16,289
Total Annual cost	197,455	210,639

3.5.2 CIP: Potato

The potato collection comprises approximately 7100 unique accessions, of which about 4600 are cultivated potato accessions (the majority being Andean native landraces), and the rest (approx. 2500) are accessions of wild species. The collection includes about 100 improved varieties, mostly from USA. About 14,000 accessions are conserved as seed in long-term storage. This collection includes duplicates that continue to be eliminated from the *in vitro* collection.

Current conservation activities include maintaining materials in the field and *in vitro*, cryopreservation of clonal materials and conservation of true seed. CIP also maintains a DNA collection for research purposes. It should be possible to rationalize some of these activities over time, especially as more accessions are moved into cryopreservation and/or seed. The costs of cryobanking are included as a one-off cost in Section 4.

Germplasm health issues are very critical but are expensive to monitor and control. Around half of the collection requires testing or cleaning but this has not been costed. ISO certification is an important part of the overall approach to plant health/quarantine management by CIP. The cost of maintaining ISO accreditation, approximately $88,000 per year, has not been included in this costing study.

Annual costs US$	2010	2015
Number of accessions	**7213**	**8188**
Annual recurring cost per accession	**171.49**	**171.49**
Total annual recurring cost of maintaining existing accessions	1,236,951	1,404,153
Annual cost of acquiring 1% additional accessions (non-compounded)	86,319	86,319
Total annual capital costs	149,284	149,284
Total Annual cost	1,472,554	1639,756

3.5.3 CIP: Sweetpotato

CIP's sweetpotato collection comprises about 8100 unique accessions. Of the accessions of known origin, about 4400 are from Latin America (60% from Peru), about 1300 from Asia/Pacific, 1000 from Africa and 200 from USA. There are about 1300 accessions of wild relatives. Efforts are underway to eliminate duplicates and it is estimated that the collection may be rationalized to a target figure of 5000 unique accessions.

About 5500 accessions are currently held *in vitro* and 3000 in the field. As with potato, more than half require health testing or cleaning. Cryopreservation is still not a routine operation, as the protocol needs refining. Once a robust protocol is available (likely within the next five 31 years) it should be possible for cryobanking to become routine. The costs of cryobanking are included as a one-off cost in Section 4. Conserving the collection as seed is made difficult/expensive because very few seeds are produced per clone due to daylength sensitivity and other problems.

Annual costs US$	2010	2015
Number of accessions	**8108**	**8979**
Annual recurring cost per accession	**151.75**	**151.75**
Total annual recurring cost of maintaining existing accessions	1,230,355	1,362,525
Annual cost of acquiring 1% additional accessions (non-compounded)	159,630	159,630
Total annual capital costs	107,896	107,896
Total Annual cost	**1,497,881**	**1,630,051**

3.8 IITA

3.8.1 IITA: Banana and Plantain

The IITA banana and plantain collection comprises 290 accessions. The collection was not included in the agreement signed with the International Treaty. The collection is maintained as living plants in the field with 173 also maintained *in vitro*. There used to be a collection at the IITA Onne Station near Port Harcourt, Nigeria, but due to security concerns it has largely been abandoned. However, there is little information about that collection, whether it is still there or can be rehabilitated, and even the extent to which it has been duplicated at the Bioversity ITC in Leuven. If it still exists and can be rescued, there will be considerable costs associated with doing so and moving it to Ibadan. Overall no new material is coming into the collection and it is not expected to expand significantly in the future unless material can be recovered from Onne.

Annual costs US$	**2010**	**2015**
Number of accessions	**290**	**290**
Annual recurring cost per accession	**66.24**	**66.24**
Total annual recurring cost of maintaining existing accessions	19,209	19,209
Annual cost of acquiring 1% additional accessions (non-compounded)	0	0
Total annual capital costs	9,317	9,317
Total Annual cost	**28,526**	**28,526**

3.8.2 IITA: Cassava

The cassava collection comprises approximately 2800 accessions, the large majority of which are of African origin. There is essentially no overlap with the CIAT collection. The collection is maintained both in the field and *in vitro*, with approximately one-third of the collection being sent annually as *in vitro* samples to Cotonou for safety duplication. The production of botanical seed is being investigated as a conservation option. A cryotank is being purchased for the conservation of cryopreserved accessions and a protocol is being refined. Cryobanking is likely to start within the next few years.

Annual costs US$	**2010**	**2015**
Number of accessions	**2783**	**2923**
Annual recurring cost per accession	**70.00**	**70.00**
Total annual recurring cost of maintaining existing accessions	194,817	204,618
Annual cost of acquiring 1% additional accessions (non-compounded)	7,516	7,516
Total annual capital costs	62,331	62,331
Total Annual cost	**264,664**	**274,465**

3.8.6 IITA: Yam

The IITA yam collection comprises about 3360 accessions of 8 different *Dioscorea* yam species. Of these, more than two-thirds are *D. rotundata* and a further 770 of *D. alata*. Around a third of the collection has been introduced into *in vitro* culture. Further research is urgently needed to improve the protocols for *in vitro* conservation, as well as disease diagnostics and cryopreservation in order to be able to optimize the structure of the collection and develop a more routine state of maintenance. The costs of conservation methods research are not specifically included in this study. However, the cost of introducing accessions from the field collection into *in vitro* is costed as an annualized cost.

Annual costs US$	2010	2015
Number of accessions	**3360**	**4724**
Annual recurring cost per accession	**63.93**	**63.93**
Total annual recurring cost of maintaining existing accessions	214,797	301,995
Annual cost of acquiring 1% additional accessions (non-compounded)	11,436	11,436
Total annual capital costs	28,862	28,862
Total Annual cost	**255,095**	**342,293**

4. One-time (one-off) and other costs

The following tables (4.1 and 4.2) indicate the major total one-time costs that are foreseen and for which funding will be required over the next one to five years, depending on the activity concerned. Some activities have a longer time-frame and will require further funding beyond the five-year time frame of this report. As these are one-time costs, and should not recur once completed, they have not been included in the summary tables in Section 3 that show annualized costs.

Table 4.1 lists the costs of „optimizing" the collections, e.g.:

- bringing seed collections into long-term storage where this is still needed;
- bringing *in vitro* collections into cryopreservation where this is feasible and;
- health testing and sanitation.

Table 4.2 gives the one-time cost of acquisition of material from the Regeneration Project that is over and above the annual "background"acquisition rate of 1% of the 2010 total (already accounted for in the annualized costings above).

In addition to these one-time costs, the ICARDA genebank manager made a strong case for an additional international scientist to manage their extensive and highly diverse collection of forage and range plants. While this was outside the terms of reference of this study and has therefore not been included in the costing presented here, the consultants were particularly sympathetic to this request and hope that a solution to this can be found. Such recruitment would, of course, increase the annual costs presented for ICARDA.

5. Some general observations and conclusion

Clonal crops

Vegetatively-propagated crops in Centre collections include the Andean root and tubers, banana, cassava, potato, sweetpotato and yam. In all cases the primary collections are held *in vitro*, where possible under slow-growth conditions, or in the field. The conservation methods and processes used are still in the process of being optimized, research remains an important component of annual costs and the structure of collections is generally not the most cost-effective for the long-term. An "ideal" conservation system for most of the clonal crops in the CGIAR genebanks might be to cryopreserve the whole collection (with a duplicate cryopreserved set held in another country), with only those accessions that are regularly required for distribution being maintained *in vitro*, and/or in the field. A further back-up of true seed, where this is possible, would be worthwhile and the use of lyophilized leaf tissue, or extracted DNA also has a role to play in certain circumstances. Given the labour intensive methods needed for conserving such crops, it is not surprising that the costs per accession are considerably higher than for seed crops and a number of efforts are underway in several of the Centres to reduce overall costs and increase security. Furthermore, vegetative materials are generally subject to considerably more diseases (especially viruses) of quarantine importance than are seed crops, and these are often very expensive to index and treat (see next section).

Germplasm health. Diseases and insects pose a major problem for genebank managers who must identify and eliminate infectious diseases, seed-borne diseases and insects that infest the seeds. Post harvest inspections are essential to ensure that the samples are free from disease and thus have greater longevity in storage. Degradation of seed as a result of various fungal and bacterial infections will, over time, reduce germination and affect the genetic integrity of the sample. Disease and insect inspection and control are also vital for enabling samples to be distributed internationally. Costs vary considerably by Centre and crop, and viruses are perhaps the most common and troublesome culprits. As noted above, the vegetatively-propagated crops generally bear more viruses than seed crops and quarantine restrictions are generally more severe. The cost of virus indexing and therapy are both very high and whereas disease-free tissue cultures provide a vehicle for distribution and quarantine clearance, the costs can be very high.

Future studies. In spite of the limitations of the study mentioned in the report, the consultants believe the results presented here are an important step forward in understanding the real costs of maintaining and distributing the Centres" germplasm collections and of making available the associated information. However, it should be noted that what is provided is only a snapshot of costs at this particular point in time. The situation is not static and will continue to evolve. For example, most of the collections are expected to continue to increase in size – although it might be possible to reduce the size of some by eliminating duplicates. The collections are also expected to acquire proportionally more accessions of wild relatives, and these are generally more difficult and expensive to maintain than cultivated accessions. In addition it might be possible to reduce the cost of conserving clonal collections through a greater use of cryopreservation, true seed and other technologies but this is likely to require a considerable up-front expenditure before any cost savings can accrue. While the costs of molecular characterization are expected to fall, the need for more virus, and other disease indexing and cleaning might well increase. For these and many other reasons, it will be important that the Consortium, Trust and genebank managers continue to monitor costs over the coming years.

CGIAR Proposal Annex 4. Table of what was included in, and excluded from the CGIAR genebanks costing study 2010.

Tool operation	Tool guidelines	What should be included: (Using activities identified by the ICWG as critical)	Does not include: (covered by another operation or considered a one-off activity or activity requiring special funds)
Acquisition	This involves the activities related to receiving and processing newly introduced accessions.	Shipping packing Permits and paperwork Most activities under this are covered elsewhere.	1. Gap identification 2. Collecting mission 3. Phenotypic characterization, multiplication, seed processing and safety duplication for initial storage (occurs with these specific activities) 4. Disease-indexing/quarantine for initial storage (occurs with these specific activities) 5. Disease-cleaning for initial storage (occurs with these specific activities).
Characterization	This is the activity of recording the characteristics of each accession, often conducted during the regeneration process.	Data collection, Recording of morphological characteristics Identification *All field and material preparation, planting, etc. is included under "Regeneration", UNLESS characterization is carried as a separate operation to regeneration.*	1. Identification of duplicates (synonymous grouping with DNA markers, Field planting to confirm with morphological chars, Management of duplicates) 2. Taxonomy/ verification (Maintenance of herbarium collection, Maintenance of seed herbaria collection. Imaging and maintaining images) 3. Molecular characterization (PCR and other molecular procedures Analysis and formation of core collection and reference sets).
Safety duplication (or security duplication)	This is the activity of sending sample accessions to different locations for safety reasons (i.e., backup collection).	Identification and checking of suitable location Selection of accessions Labelling and packing Processing and preparing certificates, permits LOAs, MTAs Postage/shipping.	1. Disease-indexing/quarantine for initial storage 2. Multiplication 3. Data entry and database management 4. Database safety backup.
Long-term seed storage	This activity is for the conservation of accessions in the long-term storage facility. Cold room.	Costs of services (electric, cooling equipment, alarm/monitoring system, security and general maintenance) Sample storage Stock management	1. Germination viability testing 2. DNA genebanks 3. Seed processing/preparation 4. Cryopreservation.

Tool operation	Tool guidelines	What should be included: (Using activities identified by the ICWG as critical)	Does not include: (covered by another operation or considered a one-off activity or activity requiring special funds)
Medium-term seed storage	This activity is for the conservation of accessions in the medium-term storage for ready dissemination upon request. Cold room.	Costs of services (electric, cooling equipment, alarm/monitoring system, security and general maintenance) Sample storage Stock management.	1. Germination viability testing 2. DNA genebanks 3. Seed processing/preparation 4. Cryopreservation, In-vitro conservation.
Field genebank		Field management/irrigation Field inspection for diseases Processing for planting (cuttings, tubers, sanitation) Germplasm harvesting (non-perennials).	1.Characterization 2. Any lab activities (e.g. health testing).
Maintenance of the cryopreserved collection		Germplasm maintenance in liquid nitrogen Cryopreserved sample monitoring.	1. Costs associated with the introduction of new material into cryopreservation.
Introduction of new accessions into cryopreservation		Multiplication and introduction of new material into cryopreservation.	1. Maintaining cryopreserved collection.
Maintenance of the *In vitro* collection	*In vitro* conservation / medium- and long-term storage, sub culturing.	*In vitro* seedling monitoring (viability/vigour check, elimination of old culture, contamination) Germplasm subculturing for conservation Germplasm maintenance using slow-growth methods.	1.Disease-cleaning 2. Disease-Indexing 3.Introduction into cryopreservation 4.Multiplication for dissemination.
Introduction or multiplication of accession in the *in vitro* collection		Introduction into cryopreservation Multiplication for dissemination or safety duplication Germplasm processing for *in vitro* introduction.	
Germination testing (or viability testing)	This is the (periodic) activity of testing germination rate of existing or newly multiplied accessions.	Germination test before storage Viability monitoring during storage.	
Regeneration	This is the activity of getting fresh seeds by planting out seeds for	Monitoring/analyzing/planning need for regeneration. Seed/planting material preparation.	1. Characterization data collection 2. Indexing/sanitation 3. *In vitro* subculture.

Tool operation	Tool guidelines	What should be included: (Using activities identified by the ICWG as critical)	Does not include: (covered by another operation or considered a one-off activity or activity requiring special funds)
	storage or dissemination.	Field preparation. Isolation cages for cross-pollinated species. Planting and field management Indexing/sanitation Harvesting of seed/tuber/ cuttings for storage. *(Includes regeneration for introduction of new accessions, multiplication for storage and multiplication for distribution, etc)*	
Seed processing	This is the activity of packing, cleaning and drying seeds – for storage or distribution.	Processing, drying, packing, labelling. Threshing/mechanical cleaning. Seed extraction, washing and cleaning for 'wet' seed. Drying operations. Moisture content testing. Sample sorting.	1. Sample identity check, inc. grow-out and DNA testing 2. Germination test before storage 3. Disease diagnostics before storage 4. Viability monitoring during storage 5. Field health inspections 6. *In vitro* costs of any kind.
Seed health testing	This activity involves the testing of seed health, often carried out upon acquisition or during regeneration process.	Disease diagnostics before storage and dissemination.	1. Cleaning 2. *In vitro* costs.
Distribution	This involves the activity of sending accessions upon request (e.g., preparation, shipment, etc).	Selection of accessions. Communication with requestor (follow up, question answering, advice). Seed sorting and weighing. Labelling and packing. Phytosanitary requirement follow-up. SMTAs issuance. Shipping/mailing.	1. Multiplication/regeneration of samples 2. Disease-indexing 3. Leaf sample preparation.
Information management	This activity includes data entering, processing and management (including catalogue preparation).	Management of hard copy documentation/field and lab books/collection sheets/MTAs/agreements. Database management and data backup. Data publication system for external users Data entry and analysis. Data verification. Effective data validation, procedures for data	1. Software applications and web development 2. Barcoding software development.

Tool operation	Tool guidelines	What should be included: (Using activities identified by the ICWG as critical)	Does not include: (covered by another operation or considered a one-off activity or activity requiring special funds)
		quality assurance. Data transfer to other platforms. Development for communication with information platforms. Online catalogues and ordering system.	
General management	This is the activity that is difficult to allocate to a specific activity (e.g., genebank manager's work).	Operation of people management, administration, planning, risk management and networking with peers. *People management* - Staff supervision Mentoring Performance evaluation. Planning HR and capacity development needs. *Administration* - Monitoring/analyzing/planning activities. Donor reporting and performance indicators. Medium- and long-term planning. Implementation plans. Annual work plans Budgeting. *Quality assurance* - Implement risk management strategy *Networking* – Collective action on crop specific genetic resources in the CGIAR. Developing genebank standards and procedures. Establish and implement global crop conservation strategies. Attend meetings and workshops organized through global crop strategies. Attend genetic resources meetings.	

CGIAR Proposal Annex. Tables of Centre x Collection cost for 2009 (adjusted where needed) as derived from the Decision Support Tool

2.1 Bioversity-Bananas

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition	25	320	12.81	15	One-off	0.00	12.81
Characterization	25	13,538	541.53	0	One-off	0.00	0.00
Field verification	80	25,548	319.35	0	10	31.94	0.00
Molecular characterization	25	3,482	139.28	0	One-off	0.00	139.28
Safety duplication shipment	25	350	14.00	0	One-off	0.00	14.00
Safety duplication at IRD	562	3,000	5.34	1,905	2.3	2.32	0.00
Maintenance of the cryopreserved collection	800	14,655	18.32	3,442	1.6	11.45	0.00
Maintenance of *in vitro* collection	1,298	183,045	141.02	18,187	1	141.02	0.00
Stock maintenance in short term storage	50	8,815	176.30	4,272	26	6.78	0.00
Introduction into cryopreservation	35	54,495	1,557.00	9,250	One-off	0.00	1,557.00
Introduction into *in vitro* collection	25	13,090	523.61	4,427	One-off	0.00	523.61
Leaf sample banking	80	12,421	155.26	5,389	16.2	9.58	0.00
Rejuvenation in greenhouses	80	64,587	807.34	2,501	10	80.73	0.00
Virus-indexing	25	0	458.00	0	One-off	0.00	458.00
Pre-indexing	100	0	211.00	0	One-off	0.00	211.00
Virus therapy	10	0	690.00	0	< One-off	0.00	276.00
In vitro multiplication & distribution	800	223,124	278.90	8,843	2	139.45	0.00
Information management	1,298	106,519	82.06	2,455	1	82.06	0.00
General management	1,298	191,022	147.17	2,770	1	147.17	0.00
Total	**1,298**	**918,012**	**6,278**		**63,456**	**652.50**	**3,191.70**

Bioversity-Bananas footnotes

- The costs of molecular characterization (ploidy and SSRs) are included as a routine means to verify the identity of accessions before they are processed for introduction into the collection.
- Field verification involves the shipping of accessions for planting and characterization in the national programmes that house the original material.

- Costs of safety duplication are for the shipment of cryopreserved material to IRD, France. The data were provided in an email (27/10/10) from Nicolas Roux (100 accessions shipped every 4 years at the total cost of $1,400). There is a charge for housing the material at IRD and this is included as a recurrent cost under a separate operation.
- A short-term stock of popularly requested material is maintained to allow a higher rate of subculture.
- New accessions are first pre-indexed, those that are found to be negative are then fully virus-indexed. Approx. 40% of the accessions requires cleaning. Pre-indexing, indexing and cleaning are costed separately according to costs provided by Nicolas Roux in an email (27/10/10).
- The information management costs include the cost of operating the Musa Germplasm Information System (MGIS) http://www.crop-diversity.org/banana, which involves the management of data from national partners. This networking modus operandi partly accounts for why these costs, as well as general management, are considerably higher than for other Centres. As such, information and general management are only included as annual costs. They are not included in the costs of acquisition.
- The costs of 10% time of the cryopreservation expert are included in General Management, together with the costs of other technical and administration staff in Leuven and Montpellier offices.
- One-off cost for optimization of the collection is for cryopreserving the remaining 350 accessions in the existing collection together with 114 anticipated accessions are included as a one-off cost.
- The costs of introducing accessions from the Regeneration Project are already covered by the project and have not been included in table 4.2.

3.2 CIAT: cassava

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition	125	2,661	21.29	0	One-off	0.00	21.29
Characterization	1,500	4,405	2.94	0	-	0.00	0.00
Identification of duplicates & integrity	233	36,180	155.28	11,795	One-off	0.00	155.28
Safety duplication	1,380	45,342	32.86	13,187	1.67	19.67	32.86
Cryopreservation	640	39,631	61.92	2,092	10	6.19	61.92
In vitro conservation	7,539	183,464	27.83	23,284	1	27.83	27.83
Health testing & thermatherapy	553	49,126	88.84	25,663	One-off	0.00	88.84
Distribution	421	32,451	77.08	3,822	7	11.01	0.00
Information management	6,592	22,462	3.41	9,094	1	3.41	3.41
General management	6,592	24,775	3.76	13,614	1	3.76	3.76
Total	**6,592**	**440,499**	**475.20**	**102,552**		**71.88**	**395.18**

CIAT: Cassava footnotes

- Molecular and biochemical characterization is recorded as a one-off operation only. However, only 15% of the cassava collection is characterized using diagnostic isozyme markers. Further characterization may be considered as a one-off optimization cost.
- Safety duplication (at CIP) is a recurring cost because it involves *in vitro* cultures that require annual subculture. Only a proportion (approx 1/3rd) of the collection is duplicated in this way, although ideally it should be 100% of the collection that is safety duplicated.
- The per accession costs of *in vitro* conservation are based on the total accessions in the collection rather than the number of subcultures.
- 20% of the collection is held as 'bonsa' plants in the greenhouse. The costs of this are absorbed in the cost of characterization and health testing, as are the costs of the herbarium
- Health testing includes the costs of some disease cleaning.

5.1: CIP: Andean roots and tubers

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition	16	5,792	361.99	603	One-off	0	361.99
Characterization	679	56,619	83.39	3,461	One-off	0	83.39
Safety duplication	1,061	22,996	21.67	1,770	1.7	12.75	21.67
Long term storage of seed	101	2,170	21.49	149	11	1.95	0.00
Field collection	768	49,565	64.54	2,900	1.7	37.96	0.00
In vitro conservation	1,011	34,088	33.72	2,690	1.3	25.94	0.00
Re-introduction into *in vitro*	50	8,612	172.23	683	20	8.61	0.00
Germination testing	25	1,202	48.07	5	90	0.53	0.00
Regeneration	25	6,452	258.09	32	90	2.87	0.00
Seed processing	25	2,289	91.57	184	90	1.02	0.00
Seed health testing	0	0	0.00	0	0	0.00	0.00
Distribution	79	9,082	114.96	396	20	5.75	0.00
Herbarium & verification	541	9,291	17.17	564	3.4	5.05	0.00
DNA genebank	400	2,153	5.38	897	4.5	1.20	0.00
Information management	1,174	36,647	31.22	1,784	1	31.22	31.22
General management	1,174	13,680	11.65	170	1	11.65	11.65
Total	**1,174**	**260,637**	**1,337**		**16,289**	**146.50**	**509.92**

CIP: Andean roots and tubers footnotes

- Acquisition costs include *in vitro* introduction. A total of 1792 accessions are expected to be introduced from various projects and collecting missions but the same 1% acquisition rate has been applied to be comparable with all Centres.
- Characterization costs include field preparation and molecular characterization.
- The procedure for health testing and cleaning of accessions is still to be put into place and is not included in the costs here.
- Distribution costs include the costs of multiplying *in vitro* materials.
- Evaluation was costed but is not included here.
- Information costs include the cost of bar-coding all accessions.

5.2 CIP: Potato

Operations	No. samples	Total cost	Total averag e cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition	135	63,962	473.79	5,088	One-off	0	473.79
Characterization & verification (DNA markers and nutritional markers)	1,000	111,754	111.75	5,097	One-off	0	111.75
Safety duplication - seed and *in vitro*	2,279	94,674	41.54	8,947	2	20.77	0.00
Long-term storage of seed	14,379	96,051	6.68	21,190	0.5	13.36	0.00
Field collection	4,049	232,161	57.34	15,287	1.8	31.85	0.00
Cryopreservation (introduction, maintenance and monitoring)	150	89,062	593.75	33,183	One-off & annual	10.00	593.75
In vitro conservation	4,568	137,721	30.15	13,506	1.6	18.84	0.00
Re-introduction into *in vitro*	150	35,033	233.55	3,280	10	23.36	0.00
Germination testing	1,100	24,691	22.45	240	10	2.24	0.00
Regeneration of seed collection	600	43,861	73.10	778	20	3.66	0.00
Seed processing & health testing	600	35,117	58.53	4,404	20	2.93	0.00
Distribution	863	91,314	105.81	4,329	7	15.12	0.00
Herbarium & verification	7,203	64,902	9.01	7,514	1	9.01	0.00
DNA genebank	1,000	5,554	5.55	2,508	7.2	0.77	0
Information management	14,379	152,773	10.62	21,850	1	10.62	10.62
General management	14,379	128,793	8.96	2,082	1	8.96	8.96
Total	**7,213**	**1,508,466**	**1,983**		**159,168**	**171.49**	**1198.88**

CIP: Potato footnotes

- Acquisition costs include post-entry quarantine and introduction into *in vitro*. Seeds may also be introduced at a lesser cost but the recurring cost of introduction, here, is based on accessions being provided as *in vitro* cultures (the most common method of introduction).
- Characterization costs include field preparation to grow out plants for morphological characterization, as well as molecular characterization for the identification (and elimination) of duplicates.
- Safety duplication includes the cost of both seed and *in vitro* duplication.
- The long-term seed storage contains almost double the number of accessions than the number considered to be unique in the entire collection. This is because duplicates have been processed into seed.
- Potato may be cryopreserved using routine methods, at least for roughly 50% of genotypes. The cost of cryopreservation was not divided into maintenance and introduction costs as with other Centres. An estimated cost was, therefore, used for maintenance.

- Field collection costs include *c*ollections in two sites and tuber storage costs. These costs will be rationalized in the years to come.
- Seed processing costs include seed health testing and cleaning.
- A cost for the recurring re-introduction of materials from the field into *in vitro* to refresh ageing cultures is included.
- Health testing is for the testing and cleaning of a backlog of around 1396 accessions *in vitro* (this might otherwise.
- Distribution costs include the costs of multiplying *in vitro* materials.
- Accessions may be introduced as seed or as vegetative materials. The costs of the latter are greater but are most frequent and are thus used to estimate recurring acquisition costs.
- Information costs include the cost of bar-coding all accessions
- Evaluation was costed but is not included here.
- One-off costs for optimization of the collection is for the cryopreservation of 750 accessions and health testing of 1,415 accessions.

7.1 CIP: Sweetpotato

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition	263	85,591	325.44	9,912	One-off	0	325.44
Characterization & verification (DNA markers and nutritional markers)	1,350	111,611	82.68	6,881	One-off	0	82.68
Safety duplication - seed & *in vitro*	6,352	115,404	18.17	10,599	1.3	13.98	0.00
Long term storage of seed	4,971	37,610	7.57	7,326	1.6	4.73	0.00
Field collection in screenhouses	3,463	113,523	32.78	13,075	2.3	14.25	0.00
Cryopreservation	40	61,567	1,539.18	8,849	One-off & annual	10.00	1539.18
In vitro conservation	5,352	161,589	30.19	13,790	1.5	20.13	0.00
Re-introduction into *in vitro*	150	54,493	363.29	4,521	10	36.33	0.00
Germination testing	600	19,972	33.29	131	10	3.33	0.00
Seed regeneration in greenhouse	700	51,510	73.59	908	20	3.68	0.00
Seed processing & health testing	600	37,759	62.93	4,404	20	3.15	0.00
Distribution (including *in vitro* multiplication)	1,728	183,248	106.05	8,668	7	15.15	0.00
Herbarium & verification	1,000	17,353	17.35	1,043	8.1	2.14	0.00
DNA genebank	1,850	11,699	6.32	4,295	4.4	1.44	0.00
Information management	8,108	117,963	14.55	12,321	1	14.55	14.55
General management	8,108	72,155	8.90	1,174	1	8.90	8.90
Total	**8,108**	**1,253,048**	**2,722**		**107,896**	**151.75**	**1970.74**

CIP: Sweetpotato footnotes

- Acquisition costs include post-entry quarantine and introduction into *in vitro*.
- Characterization costs include field preparation for morphological characterization, as well as molecular characterization.
- Safety duplication includes the cost of both seed and *in vitro* duplication.
- The cost of cryopreservation was not divided into maintenance and introduction costs as with other Centres. An estimated cost was, therefore, used for maintenance.
- Seed processing costs include seed health testing and cleaning.
- A cost for the recurring re-introduction of materials from the field into *in vitro* to refresh ageing cultures is included.
- Distribution costs include the costs of multiplying *in vitro* materials.
- Information costs include the cost of bar-coding all accessions

- Evaluation was costed but is not included here.
- Acquisitions are accepted as *in vitro* materials only. Seed processing is therefore not included in one-off costs of acquisition.
- One-off costs for optimization of the collection is for the cryopreservation of 750 accessions and health testing of 2896 accessions.

8.1 IITA: Banana and plantain

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition	0	0	0.00	0	0	0	0.00
Characterization	0	0	0.00	0	0	0	0.00
Safety duplication	0	0	0.00	0	One-off	0	0.00
In-vitro conservation	150	4,541	30.27	1,113	1.9	15.93	0.00
In vitro introduction	150	26,152	174.35	7,750	7.5	23.25	0.00
Field bank	290	5,187	17.89	111	1	17.89	0.00
Seed health testing	0	0	60.00	0	10	6	0.00
Distribution	6	261	43.49	33	20	2.17	0.00
Information management	290	892	3.08	127	1	0.50	0.00
General management	290	204	0.70	183	1	0.50	0.00
Total	**290**	**37,237**	**329.77**	**9,317**		**66.24**	**0.00**

IITA: Banana and plantain footnotes

- No further acquisitions are expected in this collection with the exception of the possible rescue of accessions from the Onne field collection.
- There is no safety duplication. The *in vitro* collection duplicates the field collection and much of the unique material is held in the Bioversity genebank. There is believed to be a small number more accessions that should still be sent to Bioversity. The cost of making this transfer of materials has not been included in costings here.
- Health testing of banana is not fully established at IITA. An estimated cost is proposed that lies somewhere between the costs of testing cassava and those of yam. Only African pests and diseases will be tested.

8.2 IITA: Cassava

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition	67	2,722	40.63	705	One-off	0.00	40.63
Characterization	2,783	17,121	6.15	2,867	One-off	0.00	6.15
Safety duplication	1,050	9,665	9.20	4,328	2.7	3.41	0.00
Cryo-preservation	-	-	-	-	-	-	-
In vitro conservation	2,637	82,131	31.15	19,733	1	31.15	0.00
In vitro introduction	289	50,962	176.34	15,062	One-off & 15	11.76	176.34
Field bank	2,783	47,882	17.21	1,065	1	17.21	0.00
Regeneration	-	-	-	-	-	-	-
Seed health testing	872	36,221	41.54	13,750	One-off	0.00	41.54
Distribution	54	2,923	54.13	301	20	2.71	0.00
Information management	2,783	8,559	3.08	1,223	1	3.08	3.08
General management	2,783	1,961	0.70	3,298	1	0.70	0.70
Total	**2,783**	**260,147**	**380.13**	**62,331**		**70.00**	**268.44**

IITA: Cassava footnotes

- A recurring cost has been added for *in vitro* introduction to account for the refreshing of *in vitro* materials from the field.
- There is a plan to start cryopreserving and characterizing the collection using SSRs but this is not costed.

8.6 IITA: Yam

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition	0	0	0.00	0	One-off	0	0.00
Characterization	516	22,576	43.75	9,234	One-off	0	43.75
Biochemical analysis	200	8,040	40.20	0	One-off	0	40.20
Safety duplication	650	27,569	42.41	162	100	0.42	42.41
Long-term storage	5,006	26,449	5.28	5,499	1	5.28	0.00
Medium-term storage	18,456	39,200	2.12	48,309	1	2.12	0.00
Field bank	1,417	35,400	24.98	6,783	15	1.67	24.98
Germination testing	1,512	56,790	37.56	23,313	10	3.76	37.56
Regeneration	1,501	153,309	102.14	11,660	20	5.11	102.14
Seed processing	1,300	32,611	25.09	26,819	20	1.25	25.09
Seed health testing	1,058	135,167	127.76	33,769	20	6.39	127.76
Distribution	1,760	41,995	23.86	5,190	7	3.41	0.00
Information management	23,462	42,453	1.81	11,359	1	1.81	1.81
General management	23,462	40,591	1.73	18,731	1	1.73	1.73
Total	**18,921**	**662,149**	**479**		**200,828**	**32.95**	**447.43**

IITA: Yam footnotes

* There are no actual costs for characterization. The cost of this activity was taken from cassava.
* The accessions from the field collection continue to be introduced into *in vitro*. This is a slow process as the protocol is not yet fully optimized. The cost of bringing accessions into *in vitro* is included as a recurring as well as an one-off cost.
* The per accession costs of biochemical/nutritional analyses are calculated from an email from Alejandra Jorge (25/10/10) and are not based on actual costs. Nutritional characterization is important for the direct use of the collection.
* Long-term storage costs are based on the number of accessions in storage rather than the total size of the collection (unlike CIAT). This is because the accessions are conserved in freezers rather than a storage room.
* One-off cost for optimization of the collection given in Table 4.1 is for processing 4000 accessions from medium-term storage and the field genebank into long-term storage. As there is a maximum capacity of 900 accessions that can be processed in a year, the costs for processing only 4,000 accessions are included here.
* Capital costs tend to be high as there is little opportunity to share facilities with other units.
* Seed health-testing is included as a recurring cost as well as an one-off cost to allow for the processing of 90% of the collection that still requires health testing.
* Total annualized costs are derived from the number of accessions in the field collection.
* Molecular characterization, cryopreservation, *in vitro* conservation and seed health testing for yam all involve non-optimized protocols that demand research resources to refine. These costs are not included.

Annex 9. Data summarised from the Tables of Centre x Collection cost for 2009 (adjusted where needed) as derived from the Decision Support Tool (Annex 5), from the CGIAR 2011 costing study

BB = cost estimated for banana maintained at Bioversity

IITA Banana = cost estimated for banana maintained at IITA

ART: Andean roots and tubers

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition - BB	25	320	12.81	15	One-off	0.00	12.81
Characterization - BB	25	13,538	541.53	0	One-off	0.00	0.00
Field verification - BB	80	25,548	319.35	0	10	31.94	0.00
Molecular characterization - BB	25	3,482	139.28	0	One-off	0.00	139.28
Safety duplication shipment - BB	25	350	14.00	0	One-off	0.00	14.00
Safety duplication at IRD - BB	562	3,000	5.34	1,905	2.3	2.32	0.00
Maintenance of the cryopreserved collection - BB	800	14,655	18.32	3,442	1.6	11.45	0.00
Maintenance of *in vitro* collection - BB	1,298	183,045	141.02	18,187	1	141.02	0.00
Stock maintenance in short term storage - BB	50	8,815	176.30	4,272	26	6.78	0.00
Introduction into cryopreservation - BB	35	54,495	1,557.00	9,250	One-off	0.00	1,557.0 0
Introduction into *in vitro* collection - BB	25	13,090	523.61	4,427	One-off	0.00	523.61
Leaf sample banking - BB	80	12,421	155.26	5,389	16.2	9.58	0.00
Rejuvenation in greenhouses - BB	80	64,587	807.34	2,501	10	80.73	0.00
Virus-indexing - BB	25	0	458.00	0	One-off	0.00	458.00
Pre-indexing - BB	100	0	211.00	0	One-off	0.00	211.00
Virus therapy - BB	10	0	690.00	0	< One-off	0.00	276.00
In vitro multiplication & distribution - BB	800	223,124	278.90	8,843	2	139.45	0.00
Information management - BB	1,298	106,519	82.06	2,455	1	82.06	0.00
General management - BB	1,298	191,022	147.17	2,770	1	147.17	0.00

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Acquisition – Cassava	125	2,661	21.29	0	One-off	0.00	21.29
Characterization – Cassava	1,500	4,405	2.94	0	-	0.00	0.00
Identification of duplicates & integrity – Cassava	233	36,180	155.28	11,795	One-off	0.00	155.28
Safety duplication – Cassava	1,380	45,342	32.86	13,187	1.67	19.67	32.86
Cryopreservation – Cassava	640	39,631	61.92	2,092	10	6.19	61.92
In vitro conservation – Cassava	7,539	183,464	27.83	23,284	1	27.83	27.83
Health testing & thermatherapy – Cassava	553	49,126	88.84	25,663	One-off	0.00	88.84
Distribution – Cassava	421	32,451	77.08	3,822	7	11.01	0.00
Information management – Cassava	6,592	22,462	3.41	9,094	1	3.41	3.41
General management – Cassava	6,592	24,775	3.76	13,614	1	3.76	3.76
Acquisition - ART	16	5,792	361.99	603	One-off	0	361.99
Characterization - ART	679	56,619	83.39	3,461	One-off	0	83.39
Safety duplication - ART	1,061	22,996	21.67	1,770	1.7	12.75	21.67
Long term storage of seed - ART	101	2,170	21.49	149	11	1.95	0.00
Field collection - ART	768	49,565	64.54	2,900	1.7	37.96	0.00
In vitro conservation - ART	1,011	34,088	33.72	2,690	1.3	25.94	0.00
Re-introduction into *in vitro* - ART	50	8,612	172.23	683	20	8.61	0.00
Germination testing - ART	25	1,202	48.07	5	90	0.53	0.00
Regeneration - ART	25	6,452	258.09	32	90	2.87	0.00
Seed processing - ART	25	2,289	91.57	184	90	1.02	0.00
Seed health testing - ART	0	0	0.00	0	0	0.00	0.00
Distribution - ART	79	9,082	114.96	396	20	5.75	0.00
Herbarium & verification - ART	541	9,291	17.17	564	3.4	5.05	0.00
DNA genebank - ART	400	2,153	5.38	897	4.5	1.20	0.00
Information management - ART	1,174	36,647	31.22	1,784	1	31.22	31.22
General management -	1,174	13,680	11.65	170	1	11.65	11.65

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
ART							
Acquisition - Potato	135	63,962	473.79	5,088	One-off	0	473.79
Characterization & verification (DNA markers and nutritional markers) - Potato	1,000	111,754	111.75	5,097	One-off	0	111.75
Safety duplication - seed and *in vitro* - Potato	2,279	94,674	41.54	8,947	2	20.77	0.00
Long term storage of seed - Potato	14,379	96,051	6.68	21,190	0.5	13.36	0.00
Field collection - Potato	4,049	232,161	57.34	15,287	1.8	31.85	0.00
Cryopreservation (introduction, maintenance and monitoring) - Potato	150	89,062	593.75	33,183	One-off & annual	10.00	593.75
In vitro conservation - Potato	4,568	137,721	30.15	13,506	1.6	18.84	0.00
Re-introduction into *in vitro* - Potato	150	35,033	233.55	3,280	10	23.36	0.00
Germination testing - Potato	1,100	24,691	22.45	240	10	2.24	0.00
Regeneration of seed collection - Potato	600	43,861	73.10	778	20	3.66	0.00
Seed processing & health testing - Potato	600	35,117	58.53	4,404	20	2.93	0.00
Distribution - Potato	863	91,314	105.81	4,329	7	15.12	0.00
Herbarium & verification - Potato	7,203	64,902	9.01	7,514	1	9.01	0.00
DNA genebank - Potato	1,000	5,554	5.55	2,508	7.2	0.77	0
Information management - Potato	14,379	152,773	10.62	21,850	1	10.62	10.62
Acquisition - Sweetpotato	263	85,591	325.44	9,912	One-off	0	325.44
Characterization & verification (DNA markers and nutritional markers) - Sweetpotato	1,350	111,611	82.68	6,881	One-off	0	82.68
Safety duplication - seed & *in vitro* - Sweetpotato	6,352	115,404	18.17	10,599	1.3	13.98	0.00
Long term storage of seed - Sweetpotato	4,971	37,610	7.57	7,326	1.6	4.73	0.00
Field collection in screenhouses - Sweetpotato	3,463	113,523	32.78	13,075	2.3	14.25	0.00

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
Cryopreservation - Sweetpotato	40	61,567	1,539.18	8,849	One-off & annual	10.00	1539.18
In vitro conservation - Sweetpotato	5,352	161,589	30.19	13,790	1.5	20.13	0.00
Re-introduction into *in vitro* - Sweetpotato	150	54,493	363.29	4,521	10	36.33	0.00
Germination testing - Sweetpotato	600	19,972	33.29	131	10	3.33	0.00
Seed regeneration in greenhouse - Sweetpotato	700	51,510	73.59	908	20	3.68	0.00
Seed processing & health testing - Sweetpotato	600	37,759	62.93	4,404	20	3.15	0.00
Distribution (including *in vitro* multiplication) - Sweetpotato	1,728	183,248	106.05	8,668	7	15.15	0.00
Herbarium & verification - Sweetpotato	1,000	17,353	17.35	1,043	8.1	2.14	0.00
DNA genebank - Sweetpotato	1,850	11,699	6.32	4,295	4.4	1.44	0.00
Information management - Sweetpotato	8,108	117,963	14.55	12,321	1	14.55	14.55
General management - Sweetpotato	8,108	72,155	8.90	1,174	1	8.90	8.90
Acquisition - IITA: Banana	0	0	0.00	0	0	0	0.00
Characterization - IITA: Banana	0	0	0.00	0	0	0	0.00
Safety duplication - IITA: Banana	0	0	0.00	0	One-off	0	0.00
In-vitro conservation - IITA: Banana	150	4,541	30.27	1,113	1.9	15.93	0.00
In vitro introduction - IITA: Banana	150	26,152	174.35	7,750	7.5	23.25	0.00
Field bank - IITA: Banana	290	5,187	17.89	111	1	17.89	0.00
Seed health testing - IITA: Banana	0	0	60.00	0	10	6	0.00
Distribution - IITA: Banana	6	261	43.49	33	20	2.17	0.00
Information management - IITA: Banana	290	892	3.08	127	1	0.50	0.00

Operations	No. samples	Total cost	Total average cost	Capital cost	Periodi-city	Annua-lized costs	One-off
General management - IITA: Banana	290	204	0.70	183	1	0.50	0.00
Acquisition - Cassava	67	2,722	40.63	705	One-off	0.00	40.63
Characterization - Cassava	2,783	17,121	6.15	2,867	One-off	0.00	6.15
Safety duplication - Cassava	1,050	9,665	9.20	4,328	2.7	3.41	0.00
In vitro conservation - Cassava	2,637	82,131	31.15	19,733	1	31.15	0.00
In vitro introduction - Cassava	289	50,962	176.34	15,062	One-off & 15	11.76	176.34
Field bank - Cassava	2,783	47,882	17.21	1,065	1	17.21	0.00
Regeneration - Cassava	-	-	-	-	-	-	-
Seed health testing - Cassava	872	36,221	41.54	13,750	One-off	0.00	41.54
Distribution - Cassava	54	2,923	54.13	301	20	2.71	0.00
Information management - Cassava	2,783	8,559	3.08	1,223	1	3.08	3.08
General management - Cassava	2,783	1,961	0.70	3,298	1	0.70	0.70
Acquisition - Yam	0	0	0.00	0	One-off	0	0.00
Characterization - Yam	516	22,576	43.75	9,234	One-off	0	43.75
Biochemical analysis - Yam	200	8,040	40.20	0	One-off	0	40.20
Safety duplication - Yam	650	27,569	42.41	162	100	0.42	42.41
Long-term storage - Yam	5,006	26,449	5.28	5,499	1	5.28	0.00
Medium-term storage - Yam	18,456	39,200	2.12	48,309	1	2.12	0.00
Field bank - Yam	1,417	35,400	24.98	6,783	15	1.67	24.98
Germination testing - Yam	1,512	56,790	37.56	23,313	10	3.76	37.56
Regeneration – Yam	1,501	153,309	102.14	11,660	20	5.11	102.14
Seed processing – Yam	1,300	32,611	25.09	26,819	20	1.25	25.09
Seed health testing – Yam	1,058	135,167	127.76	33,769	20	6.39	127.76
Distribution - Yam	1,760	41,995	23.86	5,190	7	3.41	0.00
Information management - Yam	23,462	42,453	1.81	11,359	1	1.81	1.81
General management - Yam	23,462	40,591	1.73	18,731	1	1.73	1.73

Annex 10. Definition of cacao collection management activities following the model of the CGIAR Decision-Support Tool (Reference: Table 4 of the CGIAR costing study)

Operation	Description
Acquisition	Activities related to receiving and processing newly introduced accessions. Includes: Shipping packing; Permits and paperwork; Most activities under this are covered elsewhere.
Field genebank	Activity related to the maintenance of the cacao trees on site. Includes: Field management and irrigation; Field inspection for diseases; Processing for planting (cuttings, sanitation).
Characterization	Activity of recording the characteristics of each accession, often conducted during the regeneration process. Includes: Data collection; Recording of morphological characteristics; Identification.
Regeneration	Activity of replacing trees with new planting materials. Includes: Monitoring/analyzing/planning need for regeneration; Planting material preparation; Field preparation; Planting and field management; Indexing/sanitation.
Health testing	Activity often carried out upon acquisition or during regeneration process. Includes: Disease diagnostics before planting and dissemination.
Maintenance of *In vitro* collection	Activity for the maintenance of accessions for ready dissemination upon request. Includes: *In vitro* monitoring (viability/vigour check, elimination of old culture, contamination); Germplasm sub-culturing for conservation.
Introduction/ multiplication of accession *in vitro*	Includes: Introduction into cryopreservation; Multiplication for dissemination or safety duplication; Germplasm processing for *in vitro* introduction.
Maintenance of the cryopreserved accessions	Activity for the conservation of accessions in long-term storage facility. Includes: Germplasm maintenance in liquid nitrogen; Cryopreserved sample monitoring.
Introduction of accessions into cryopreservation	Activity for the conservation of accessions in long-term storage facility. Includes: Multiplication and introduction of new material into cryopreservation.
Safety duplication (or security duplication)	Activity of sending sample accessions to different locations for safety reasons (i.e. backup collection). Includes: Identification and checking of suitable location; Selection of accessions; Labelling and packing; Processing and preparing certificates, permits; LOAs, MTAs, Postage/shipping.
Distribution	Activity of sending accessions upon request (e.g., preparation, shipment, etc). Includes: Selection of accessions; Communication with requestor (follow up, question answering, advice); Seed sorting and weighing; Labelling and packing; Phytosanitary requirement follow-up; issuing SMTAs; Shipping/mailing.
Information management	Activity includes data entering, processing and management (including catalogue preparation). Includes: Management of hard copy documentation/field and lab books/collection sheets/MTAs/agreements; Database management and data backup; Data publication system for external users; Data entry and analysis; Data verification; Effective data validation, procedures for data quality assurance; Data transfer to other platforms; Development for communication with information platforms; Online catalogues and ordering system.
General management	Activity that is difficult to allocate to a specific activity category (e.g. genebank manager's work). Includes: Operation of people management, administration, reporting, planning, risk management, quality assurance, and networking with peers.

Annex 11. Summary of the costs of the GSCC with footnotes detailing the data source

Operation (as described in Annex 10 above)	**Estimated No. of accessions**	FN*	**Cost per accession**	FN*	**Capital cost**	FN*	**Total cost**	**Periodicity**
Acquisition	20	1	255	2	520	3	5,620	Annual
Field genebank	2,500	4	38	5	7,678	6	102,678	Annual
Characterization - morphological	200	7	21	8	800	9	5,000	Annual
Characterization - molecular	200	10	101	11	1,800	12	22,000	Annual
Regeneration	200	13	105	14	1,600	15	22,600	Annual
Health testing	200	16	292	17	9,200	18	67,600	Annual
Maintenance of *in vitro* collection	250	19	28	20	1,000	21	8,000	Annual
Introduction/ multiplication of accession *in vitro*	75	22	231	23	3,300	24	20,625	Annual
Maintenance of the cryopreserved accessions	300	25	18	26	1,200	27	6,600	Annual
Safety duplication (or security duplication)	300	31	25	32	1,500	33	9,000	Annual
Distribution	200	34	74	35	1,000	36	15,800	Annual
Identification of duplicates and integrity	200	43	155	44	10,200	45	41,200	Annual
Information management	2,500	37	15	38	2,500	39	40,000	
General management	2,500	40	8	41	2,500	42	22,500	Annual
					Total of annual costs		**389,223**	**Annual**
Introduction of accessions into cryopreservation	300	28	1,557	29	79,200	30	546,300	One-off
					Total of one-off costs		**546,300**	**One-off**

* **Footnotes (FN) for the above table:**

1 Estimated annual acquisition of new accessions

2 Average based on acquisition activities of Bioversity (banana), CIAT (cassava) CIP (Andean roots and tubers, potato and sweetpotato) and IITA (cassava) for a total of 631 accessions with total cost of 161,048 USD

3 Estimated at 26 USD per accession based on capital costs of CIP (Andean roots and tubers, potato and sweetpotato) and IITA (cassava) for a total of 631 accession with total cost of 16,323 USD

4 Estimated size of the GSCC

5 Average based on field genebank activities of CIP (Andean roots and tubers, potato and sweetpotato) and IITA (banana and cassava) for a total of 12,770 accessions with total cost of 483,718 USD

6 Estimated at 3 USD per accession based on capital costs of CIP (Andean roots and tubers, potato and sweetpotato) and IITA (banana and cassava) for a total of 12,770 accession with total cost of 39,221 USD

7 Estimated number of accessions to be introduced and/or regenerated every year

8 Average based on basic characterization activities of Bioversity (banana), CIAT (cassava), CIP (Andean roots and tubers) and IITA (yam) for a total of 5503 accessions with total cost of 114,259 USD

9 Estimated at 4 USD per accession based on capital costs of CIP (Andean roots and tubers) and IITA (cassava and yam) for a total of 3978 accession with total cost of 15,562 USD

10 Estimated number of priority accessions per year

11 Average based on molecular characterization activities of Bioversity (banana), CIAT (cassava), CIP (potato and sweetpotato) and IITA (cassava) for a total of 2608 accessions with total cost of 263,027 USD

12 Estimated at 9 USD per accession based capital on costs of CIP (potato and sweetpotato) and IITA (cassava) for a total of 2583 accession with total cost of 23,773 USD

13 Estimated number of accessions regenerated per year

14 Average based on regeneration activities of CIP (Andean roots and tubers) and IITA (yam) for a total of 1526 accessions with total cost of 159,761 USD

15 Estimated at 8 USD per accession based on capital costs of CIP (Andean roots and tubers) and IITA (cassava and yam) for a total of 1526 accessions with total cost of 11,692 USD

16 Estimated number of cacao accessions tested every year (for distribution, acquisition and regeneration)

17 Average based on activities of health testing (virus pre-indexing, indexing and therapy) of Bioversity (banana) for a total of 135 accessions with total cost of 39,450 USD

18 Estimated at 46 USD per accession based on capital costs of CIAT (cassava) for a total of 553 accessions with total cost of 25,663 USD

19 Estimated number of cacao accessions expected to be distributed from the GSCC every year

20 Average based on activities of maintaining accessions *in vitro* of CIAT (cassava), CIP (Andean roots and tubers, potato and sweetpotato) and IITA (banana and cassava) for a total of 21,257 accessions with total cost of 603,534 USD

21 Estimated at 4 USD per accession based on capital costs of CIP (Andean roots and tubers, potato and sweetpotato) and IITA (banana and cassava) for a total of 21,257 accessions with total cost of 74,116 USD

22 Estimated number of new cacao accessions requested for distributed from the GSCC every year

23 Average based on activities of introducing accessions *in vitro* of Bioversity (banana), CIP (Andean roots and tubers, potato and sweetpotato) and IITA (banana and cassava) for a total of 814 accessions with total cost of 188,342 USD

24 Estimated at 44 USD per accession based on capital costs of Bioversity (banana), CIP (Andean roots and tubers, potato and sweetpotato) and IITA (banana and cassava) for a total of 814 accessions with total cost of 35,723 USD

25 Estimated number of accessions to be maintained in cryopreservation

26 Average based on activities of maintenance of the cryopreserved accessions of Bioversity (banana) for a total of 800 accessions with total cost of 14,655 USD

27 Estimated at 4 USD per accession based on capital costs of Bioversity (banana) for a total of 800 accessions with total cost of 3442 USD

28 Estimated number of accessions to be introduced into cryopreservation

29 Average based on activities of introduction of accessions into cryopreservation of Bioversity (banana) for a total of 35 accessions with total cost of 54,495 USD

30 Estimated at 264 USD per accession based on capital costs of Bioversity (banana) a total of 35 accessions with total cost of 9250 USD

31 Estimated number of accessions for security duplication in a distant location (in addition to the accessions in cryopreservation).

32 Average based on activities of security duplication of CIAT (cassava), CIP (Andean roots and tubers,) and IITA (cassava and yam) for a total of 4141 accessions with total cost of 105,572 USD

33 Estimated at 5 USD per accession based on capital costs of Bioversity (banana), CIP (Andean roots and tubers, potato and sweetpotato) and IITA (banana and cassava) for a total of 4141 accessions with total cost of 19,447 USD

34 Estimated number of accessions distributed every year

35 Average based on activities of distribution of CIAT (cassava), CIP (Andean roots and tubers, potato and sweetpotato) and IITA (banana, cassava and yam) for a total of 4911 accessions with total cost of 361,274 USD

36 Estimated at 5 USD per accession based on capital costs of CIP (Andean roots and tubers, potato and sweetpotato) and IITA (banana, cassava and yam) for a total of 4911 accessions with total cost of 22,739 USD

37 Estimated number of accessions of the GSCC

38 Average based on activities of information management of Bioversity (banana), CIAT (cassava), CIP (Andean roots and tubers, potato and sweetpotato) and IITA (cassava) for a total of 27,742 accessions with total cost of 422,461 USD

39 Estimated at 1 USD per accession based on capital costs of Bioversity (banana), CIP (Andean roots and tubers, potato and sweetpotato) and IITA (cassava) for a total of 27,742 accessions with total cost of 39,633 USD

40 Estimated number of accessions of the GSCC

41 Average based on general management of collection of Bioversity (banana), CIAT (cassava), CIP (Andean roots and tubers and sweetpotato) and IITA (banana, cassava and yam) for a total of 43,707 accessions with total cost of 344,388 USD

42 Estimated at 1 USD per accession based on capital costs of Bioversity (banana), CIAT (cassava), CIP (Andean roots and tubers and sweetpotato) and IITA (banana, cassava and yam) for a total of 43,707 accessions with total cost of 39,940 USD

43 Estimated number of accessions verified for identification of duplicates and integrity

44 Average based on activities of identification of duplicates and integrity of CIAT (cassava) for a total of 233 accessions with total cost of 36,180 USD

45 Estimated at 51 USD per accession based on capital costs of CIAT (cassava) for a total of 233 accessions with total cost 11,795 USD

46 Estimated number of new germplasm collected annually

47 Estimated cost per sample of collecting based on pers. communication

48 Estimated cost of travel and equipment per year

Annex 12. References

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Annex 13. List of acronyms and abbreviations

ABS	Access and Benefit Sharing
ACIAR	Australia Centre for International Agricultural Research
ARS	Agricultural Research Service of the USDA, USA
AVRDC	World Vegetable Center
PBCU	Black Pod Cocoa Unit, Solomon Islands
BCCCA	Biscuit, Cake, Chocolate and Confectionery Association of the UK
Bioversity	Bioversity International (formerly IPGRI and IBPGR), Italy
BP	Black pod disease
CABI	Centre for Agriculture and Biosciences International, UK
CacaoNet	Global Network for Cacao Genetic Resources
CANGIS	CacaoNet Germplasm Information System
Caobisco	Association of the Chocolate, Biscuits and Confectionery Industries of Europe
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica
CBD	Convention on Biological Diversity
CCD	Conservation and Development Centre, Ecuador
CCI	Cocoa and Coconut Institute, Papua New Guinea
CEPEC	Centro de Pesquisas do Cacau, Brazil
CEPICAFE	Central Piurana de Cafetaleros, Peru
CEPLAC	Comissão Executiva do Plano da Lavoura Cacaueira of CEPEC, Brazil
CFC	Common Fund for Commodities, The Netherlands
CGIAR	Consultative Group on International Agricultural Research
CGR	Cacao genetic resources
CGRFA	FAO Commission on Genetic Resources for Food and Agriculture
CHRC	Chumphon Horticultural Research Centre, Thailand
CIAT	International Center for Tropical Agriculture of the CGIAR
CIP	International Potato Center of the CGIAR
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement, France
CNRA	Centre national de recherche agronomique, Côte d'Ivoire
COPAL	Cocoa Producers Alliance, Nigeria
CPB	Cocoa pod borer
CPCRI	Central Plantation Crops Research Institute, India
CPQP	Cocoa Productivity and Quality Programme Facility
CRAF	Centre de recherche agronomique pour la zone forestière, Togo
CRA Ltd.	Cocoa Research Association, Ltd., UK
CRA-SB	Centre de recherche agricole Sub Benin
CRIG	Cocoa Research Institute of Ghana
CRIN	Cocoa Research Institute of Nigeria
CRU/UWI	Cocoa Research Unit, University of the West Indies, Trinidad and Tobago
CSSV	Cocoa Swollen Shoot Virus
DNA	Deoxyribo-nucleic acid
ECA	European Cocoa Association

EIC-ECICC	Estación de Investigaciones de Cacao, Cuba
FAO	Food and Agriculture Organization of the United Nations, Italy
FCC	Federation of Cocoa Commerce Limited, UK
FEDECACAO	Federación Nacional de Cacaoteros, Colombia
FHIA	Fundación Hondureña de Investigación Agrícola, Honduras
FP	Frosty pod disease
GCCUS	Global Cacao Conservation and Use Strategy
GIS	Geographic Information System
GPA	Global Plan of Action on PGRFA of the FAO
GPS	Global Positioning System
GREST	Genetic Resources Evaluation and Selection Tool
GRIN	Germplasm Resources Information Network, USA
GSAC	Global Strategic Active Collection
GSBC	Global Strategic Base Collection
GSCC	Global Strategic Cacao Collection
IBPGR	International Board for Plant Genetic Resources (now Bioversity International)
IC3	International Cacao Collection at CATIE, Costa Rica
ICA	Instituto Agronomico de Campinas, Brazil
ICCO	International Cocoa Organization
ICCRI	Indonesian Coffee and Cocoa Research Institute, Indonesia
ICGD	International Cocoa Germplasm Database
ICG,T	International Cocoa Genebank, Trinidad and Tobago
ICI	International Cocoa Initiative
ICQC,R	International Cocoa Quarantine Centre, Reading, UK
ICS	Imperial College Selection
ICT	International Clone Trial
ICT	Instituto de Cultivos Tropicales, Tarapoto, Peru
IDIAF	Instituto Dominicano de Investigaciones Agropecuarias y Forestales, Domenican Republic
IDH	Dutch Government Sustainable Trade Initiative
IICA	Inter-American Institute for Cooperation on Agriculture
IITA	International Institute of Tropical Agriculture, Nigeria
INGENIC	International Group for the Genetic Improvement of Cocoa
INIA	Instituto Nacional de Investigaciones Agrícolas, Venezuela
INIAP	Instituto Nacional de Investigaçâo Agrária e des Pescas, Ecuador
IPGRI	International Plant Genetic Resources Institute (now Bioversity International)
IPPC	International Plant Protection Convention
IPRs	Intellectual Property Rights
IRAD	Institut de recherche agricole pour le développement, Cameroon
ISC	Interim Steering Committee
ITIS	Integrated Taxonomic Information System
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
LIFFE	London International Financial Futures and Options Exchange
MAS	Marker Assisted Selection
MCB	Malaysia Cocoa Board, Malaysia

MHOCGA	Mabaruma/Hosororo Organic Cocoa Growers Association, Guyana
MLS	Multi-Lateral System of exchange of the ITPGRFA
MMSP	Mabang Megakarya Selection Programme
MTA	Material Transfer Agreement
NGO	Non Governmental Organization
PACS	Payments for Agro-Biodiversity Conservation Services
NYSE	New York Stock Exchange
PGR	Plant genetic resources
PGRFA	Plant genetic resources for food and agriculture
SE	Somatic embryogenesis
SGRP	System-wide Genetic Resources Programme of the CGIAR
SINGER	System-wide Information Network for Genetic Resources of the CGIAR
SMTA	Standard Material Transfer Agreement
SNP	Single Nucleotide Polymorphism (SNP)
SSR	Microsatellites or simple sequence repeats
STCP	Sustainable Tree Crops Programme, based at IITA-Ghana
TF	Task Force
Trust	Global Crop Diversity Trust, Italy
UESC	Universidade Estadual de Santa Cruz, Brazil
UFLA	Universidade Federal de Lavras, Brazil
UNA	Universidad Nacional Agraria La Molina, Peru
UNAN	Universidad Nacional Autónoma de Nicaragua, Laboratorio de Biociencia, Managua, Nicaragua
UNAS	Universidad Nacional Agraria de la Selva, Tingo María, Peru
UNSAAC	Universidad Nacional de San Antonio Abad del Cuzco, Cuzco, Peru
USAID	United States Agency for International Development
USDA	United States Department of Agriculture, USA
USMARC	University of Southern Mindanao Agricultural Research Centre, Philippines
UWI	The University of The West Indies
V4C	Vision for Change project
VARTC	Vanuatu Agricultural Research and Technical Centre, Vanuatu
VSD	Vascular streak dieback disease
WACRI	West Africa Cocoa Research Institute
WBD	Witches' broom disease
WCF	World Cocoa Foundation, USA
WIEWS	World Information and Early Warning System

Annex 14. Useful web links

ACIAR	www.aciar.gov.au
AVRDC	www.avrdc.org
Bioversity	www.bioversityinternational.org
CABI	www.cabi.org
CacaoNet	www.cacaonet.org
Caobisco	www.caobisco.com
CATIE	www.catie.ac.cr
CBD	www.cbd.int
CEPICAFE	www.cepicafe.com.pe
CEPLAC	www.ceplac.gov.br
CFC	www.common-fund.org
CGIAR	www.cgiar.org
CIRAD	www.cirad.fr
CNRA	www.cnra.ci
COPAL	www.copal-cpa.org
CPCRI	www.cpcri.gov.in
CPQP	www.idhsustainabletrade.com/CPQP
CRA Ltd.	www.cocoaresearch.org.uk
CRIG	www.crig.org
CRIN	www.crin-ng.org
CRU/UWI	www.sta.uwi.edu/cru
ECA	www.eurococoa.com
FAO	www.fao.org
FCC	www.cocoafederation.com
FEDECACAO	www.fedecacao.com.co
FHIA	www.fhia.org.hn
GPA	www.fao.org/agriculture/crops/core-themes/theme/seeds-pgr/gpa
ICA	www.ica.gov.co
ICCO	www.icco.org
ICCRI	www.iccri.net
ICGD	www.icgd.rdg.ac.uk
ICQC,R	www.icgd.rdg.ac.uk/contact_ICQC.php
ICT	www.ict-peru.org
IDIAF	www.idiaf.gov.do
IDH	www.idhsustainabletrade.com
IICA	www.iica.int
IITA	www.iita.org
INGENIC	http://ingenic.cas.psu.edu
INIA	www.inia.gov.ve
IPPC	www.ippc.int
IRAD	www.irad-cameroon.org

ITIS	www.itis.gov
ITPGRFA	www.planttreaty.org
Kraft	www.kraftfoodscompany.com
Mars	www.mars.com/global/brands/cocoa-sustainability-home.aspx
MCB	www.koko.gov.my
Nestle	www.nestlecocoaplan.com
Trust	www.croptrust.org
UESC	www.uesc.br
UFLA	www.ufla.br
UNAN	www.unan.edu.ni
UNAS	www.unas.edu.pe
UNSAAC	www.unsaac.edu.pe
USAID	www.usaid.gov
USDA/ARS	www.ars.usda.gov
USMARC	www.usm.edu.ph
WCF	www.worldcocoafoundation.org
WIEWS	http://apps3.fao.org/wiews/wiews.jsp

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CacaoNet
Global Network for Cacao Genetic Resources