Collective Action for Rehabilitation of Global Public Goods
CGIAR Genetic Resources Systems - Phase 2 (GPG2)

Activity 2.4

(Develop and disseminate decision-support tools to
enhance the cost-effectiveness of collection management)

Final Report

Evaluating Cost-Effectiveness of Collection Management: *Ex-situ* Conservation of Plant Genetic Resources in the CG System

March 2010

Activity Leader:
D. Horna,
M. Smale (until June 2008)

Task Force Members
D. Debouck (CIAT), D. Dumet (IITA), J. Hanson (ILRI), T. Payne (CIMMYT),
R. Sackville-Hamilton (IRRI), I. Sanchez (WARDA), H. D. Upadhyaya (ICRISAT), I. van den Houwe (BIOVERSITY)

Contributors:
S. Almazan (IRRI), G. L. Capilit (IRRI), A. Ciprian (CIAT), M. Cuervo (CIAT), B. Espinoza (CIMMYT), R. Escobar (CIAT), C.L.L. Gowda (ICRISAT), F. Guzman (IRRI), A. Hernandez (CIAT), A. Jorge (BIOVERSITY),G. Mafla (CIAT), V. M. Manyong (IITA), C. Ocampo, (CIAT), A. Ogundapo (IITA), R. Reaño (IRRI), V.G. Reddy (ICRISAT), K.N. Reddy (ICRISAT), M. Rivas (CIMMYT), L.G. Santos (CIAT), D.V.S.S.R. Sastry (ICRISAT), S. Singh (ICRISAT), S. Taba (CIMMYT), O. Toro (CIAT)

TABLE OF CONTENTS

List of Figures

List of Tables

Acknowledgments

This activity involved an intensive data collection. To complete this activity we counted with the help of several staff across center that gladly provided us with information or guided us to the right sources. We would like to thank:

CIAT: C. Bejarano, M. Cortez, J. Martinez, J. Mena, A. Palau, L. M. Quintana, J. Soto, J. Uribe
CIMMYT: V. Chavez J. Gumafelix
ICRISAT: R.P. Thakur, A.G. Girish, B. Ashok Kumar
IITA: A. Bamikole
IFPRI: P. Zambrano, S. Yan
ILRI: J.Bongo
IRRI: M. Aquino, P. Gonzales, A. Telosa, M. Telosa, T. Santos
Consultants: V. Komerell, B. Koo

In particular, we would like to thank Brigitte La Liberte (project coordinator until January this year) for the remarkable support in completing this activity.

SECTION 1

Introduction

Conserving and managing germplasm is a long-term activity that requires a long-term perspective, but genebanks are typically funded on a short-term basis (Koo *et al.* 2004). Phase 1 of the project "Collective Action for the Rehabilitation of Global Public Goods in the CGIAR Genetic Resources System" (GPG), the thorough analyses of conservation costs previously undertaken by the Systemwide Genetic Resources Program (SGRP) (summarized in Koo *et al.* 2004), and other economics research about the benefits of genebanks have demonstrated the importance of sustained funding and the high expected benefits of ex-situ conservation relative to costs, assuming "good practices" (summarized in Smale and Drucker, 2007; Smale and Koo 2003; for the case of a large national genebank, see also Day-Rubenstein *et al.* 2006).

The expansion of genebank collections from the 1970s through the 1990s led to management challenges. These included the duplication of accessions, backlogs in regeneration, and insufficient or untimely provision of information to users (Altoveros and Rao 1998; Engels and Rao 1998; Koo and Wright 2008)[1]. At the same time, there was increasing recognition that integration and coordination of the collections as a global system offered important functional and economic advantages. In 1995, SGRP commissioned an external review of the CGIAR genebanks to provide an assessment of what was needed to meet conservation standards. The first phase of the GPG project addressed the main recommendations from this review, including amelioration of genebank facilities and genebank procedures including reducing backlogs on regeneration, germination tests and plant health screening

[1] Fowler and Hodgkin (2004) report that between 1974 and 1996, the number of long-term storage facilities in the world grew from five or six to 76, with an estimated 6.2 million accession housed by gene banks located in 137 countries. Experts estimated that by the mid-1990s, only five percent of the rice, maize, and wheat gene pools remained unrepresented among these accessions. These authors caution that : a) coverage is much lower for many crops b) it is not possible to catalog a crop's gene pool with any precision and c) while some duplication is necessary to safeguard accessions, the redundancy of materials could be substantial. Regeneration of large collections is costly. Thus, short-term budgetary constraints could endanger the longer-term viability of such collections.

The second phase of the project (GPG2) built on the progress made in the first phase, with a focus on establishing good standards and practices in genebank operations and encouraging a systems perspective. The challenge, as viewed by those engaged in this project, was not to increase the numbers of accessions, but to ensure the quality, security, accessibility and sustainability of the in-trust collections. An underlying assumption was that a better allocation of resources will lead to better performance. As genebank managers pointed out, there was a need to examine the cost-effectiveness of operations (output per cost).

The goal of activity 2.4 of the GPG2 project was to develop and disseminate a computerized tool that will support strategic decision-making by genebank managers. The objectives of this document are to a) provide a conceptual framework for the tool and b) demonstrate how the tool can be used to evaluate the effects of decisions on the allocation of resources across operations. Effects of decisions are illustrated by two types of outputs: a) cost summary reports and b) sensitivity analysis with simulations. Thus, it is expected that genebank managers will be able to apply the tool to answer management questions and craft strategies in pursuit of good practices or to enhance their performance. Eventually, the tool could be generalized in order to explore the effects of resource allocation decisions within an integrated genebank system.

This study is divided into 10 sections. The second section discusses some fundamental concepts on which the framework is based. This section describes the type of information genebank managers need to apply to the tool and the outputs that can be produced. Notice that a single set of cost data (representing one point in time) allows us to minimize cost only with respect to the technology and set of practices represented by those data. To draw conclusions concerning optimal allocation of resources within a single bank over time, and among banks, additional points corresponding to other technologies and practices are needed. Two additional analyses that can be conducted with additional observations: sensitivity analysis and regression analysis. Sections 3 -8 summarize the information collected for selected genebanks. Comparison across centers is rather difficult because of different crop mandates, locations, and technological conditions. Section 9 discusses some factors affecting costs effectiveness within and across genebanks. The concluding section includes some considerations for the implementation of this decision support tool for evaluating cost-effectiveness periodically.

Scope of the Study

This report is one of 3 main expected outputs of Activity 2.4 of the project: Collective Action for the Rehabilitation of Global Public Goods in the CGIAR Genetic Resources System: Phase 2. The objective of the activity was to Develop and disseminate a decision-support tool to enhance the cost-effectiveness of collection management. The other 2 expected outputs under this activity are: the Decision Support Tool (DST) and the guide for users. During the implementation of the activities, important genebank costs information was collected for selected genebanks: CIAT, CIMMYT, ICRISAT, IITA, ILRI and IRRI. In the following sections we describe the data collected and present the main finding for each one of these genebanks. The genebanks costs are reported per operations. The costs relate basically to critical operations rather than user oriented operations as define in the sustainability plan (SGRP 2009).

SECTION 2

Evaluating Cost-Effectiveness of Collection Management: A Methodological Framework

D. Horna and M. Smale

This section presents the basic concepts, tools and methods used to understand and estimate the costs of genebank operations. The section also provides a brief description of the Decision Support Tool (DST). The DST is an excel files developed to capture in a systematic way inputs used and related costs of genebank activities and operations. In the final part of this section we proposed ways in which the information collected can be analyzed.

1. Basic concepts

1.1 Genebank Operations

There is no disagreement over the main purpose of a genebank, which is to conserve genetic material and make it available to users. However, a review of genebank protocols suggests that agreement has not yet been reached on a general classification of activities and related terminology (Rao *et al.* 2006; Taba *et al.* 2004). Pardey *et al.* (2001) and Koo *et al.* (2003) group genebank activities into operations performed to reach genebank objectives. Orienting their description toward “best practices,” Calles *et al.* (2007) classify genebank activities and inputs according to the specific objectives. Many operations are comparable across centers, but other activities are specific to reproduction system of the crop, such as propagation and multiplication strategies. Seed propagated crops like wheat or rice are the easiest to handle and can be conserved for longer periods than clonal crops like cassava or banana (Rao *et al.* 2006).

In this study the focus is placed on critical genebank operations and not on user oriented operations as defined in the sustainability plan of the CGIAR Centres’ genebanks. An operation is understood as a cluster of activities and a number of operations are performed in order to reach genebank objectives and thus genebank goals. Conservation and use of the genetic material are the two main goals of a germplasm bank. Specific objectives for achieving better conservation of genetic materials are:

- To cover the gene pool as much as possible
- To ensure the security (physical security and viability) of the genetic material
- To maintain its genetic integrity

Specific objectives for achieving a wider use of genetic materials are:

- To ensure the availability of the material to users
- To distribute the material
- To provide information

1.2 Best Practices

The issue of quality standards is central to the management of any genebank. Genebanks in the CG system have operated with two sets of conservation standards: acceptable and preferred. Acceptable standards are considered to be minimal but adequate, while preferred standards guarantee better and safer conservation conditions. Evidently, meeting the preferred standards is more costly. Acceptable standards have been more frequently adopted as a consequence of budget constraints, leading to wide variation in quality standards across centers.

The CG genebanks are now directed toward "best practices," which is a more dynamic, less easily defined concept of quality management. Genebank managers have not yet reached a consensus regarding the operational meaning of best practices. In some cases, "best practices" are viewed as activities that mitigate the risks that impede the achievement of objectives (conservation and use). In other cases, "best practices" are simple understood as the most effective practices given the technology that is currently available to the research center. From the economic perspective, we understand best practices as the costs incurred in order to reduce the chances of mistakes in technical procedures or in the delivery and distribution of genetic materials and related information to use. Standard practices have been proposed and implemented for minimizing risk thresholds based on knowledge and information accumulated over the years. Therefore the concept of best practices is directly linked to that of risk management. Ideally, implementing best practices based on performance levels as expressed by a set of indicators should minimize spending subject to an acceptable threshold of risk, a current conservation technology, and a current organization of collections. This would be one point of optimal resource allocation. Other optima would correspond to other conservation technologies, other risk thresholds, or a different organization of collections in the genebank system.

1.3 Performance indicators

Performance indicators measure the quality of an operation or a system in quantitative terms. In general, good performance indicators should be simple and measurable, while capturing the essential features of a complex system. The performance of the genebank is determined by the level of integration in the flow of operations. Therefore performance is not an abstraction, in the sense that quality or output are measured against a timetable, or against a pre-established standard or target. The delay in one operation will have consequences on the performance of the linked operations.

The selection of appropriate performance indicators for a genebank however proved to be a difficult task[2]. Genebanks make use of variable, fixed and quasi-fixed inputs to regenerate the material and most importantly in order to maintain a low index of genetic erosion. If the genebank is not performing well and genetic erosion is high (or higher than the standard level/best practice recommendation), how should the manager allocate inputs in order to reduce the index of genetic erosion? Increasing a technician's time in order to regenerate wild rice will most likely reduce the index of genetic erosion, but by how much? Thus, both the effect of input use on performance and the effect of performance on costs are difficult to grasp. At this stage of the activity the focus was placed on estimating the genebank costs. The relationship with performance indicators although important might not be practical at this stage of the development of the decision support tool. It is however important to have this concept in mind for the development and implementation of the tool. Moreover, identifying performance indicators for the CGIAR genebanks is another activity (No. 6.1.2) of the GPG2 project.

1.4 Costs Effectiveness

The analysis of the cost-effectiveness of a genebank is basically a comparison of relative costs to outputs. Cost-effectiveness is different from cost-benefit analysis in which a

[2] Annex 2 summarizes an attempt to link performance to cost.

monetary value is assigned to measure an effect. A number of factors can affect the costs effectiveness of conservation and management of plant genetic resources in the CGIAR centres' genebanks. The challenge of discussing costs effectiveness in this context is the availability of information. There is limited costs information gathered about the genebank costs in the CG centers. A comparison across centers is not necessarily possible as the centers have mandates over different sets of materials. Moreover, as mentioned above, there is no necessarily an agreement on the flow of operations and vocabulary used to refer to activities or operations. Despite these limitations it is possible to arrive to early conclusions genebank performance using simulated scenarios.

2. Analysis of Genebank Costs

A review of CGIAR genebanks in 1999 demonstrated the need for upgrading management of the in-trust collections[3]. In response, SGRP organized a series of economic studies to determine the costs of the maintaining collections and proposed upgrade. The GPG project was established to facilitate the upgrade. During the first phase of the project, which started in 2003, in close consultation with several CG genebank managers, Koo et al (2004) compiled and analyzed genebank cost information.[3]

The analytical framework for the cost studies was the micro-economic theory of production (Pardey *et al.* 2001). A genebank, like a firm, is organized to produce outputs (numbers of accessions characterized, stored, regenerated, etc.). Production decisions involve choosing which outputs to produce in which amounts, with which mix of inputs and input quantities. In the framework of economic decision-making, optimal resource allocation can be achieved either by minimizing the costs of operation given fixed physical resources and existing technology or by maximizing production subject to a fixed budget and existing technology. By duality theory, it has been proven that both approaches produce the same production possibility frontier. The production possibility frontier then traces the points corresponding to efficient resource allocations.

This approach selected by Koo *et al.* (2004) was cost minimization—for a very important, practical reason. Most of the benefits of genebank collections are public goods

[3] These studies provided evidence to enable the Global Crop Diversity Trust to make realistic resource projections for an endowment to support globally important collections of crop diversity in perpetuity, including those held by the Centres (http://www.sgrp.cgiar.org/?q=node/176).

whose values are both expensive to estimate and likely to be unreliable estimates (see Smale and Koo 2003). By comparison, the costs of genebank operations are relatively easy to estimate with a fair degree of precision. Pardey *et al.* (2001) reasoned that if the costs of conserving an accession are shown to be lower than any sensible lower-bound estimate of the corresponding benefits, for many decisions, it may not be necessary to estimate benefits.

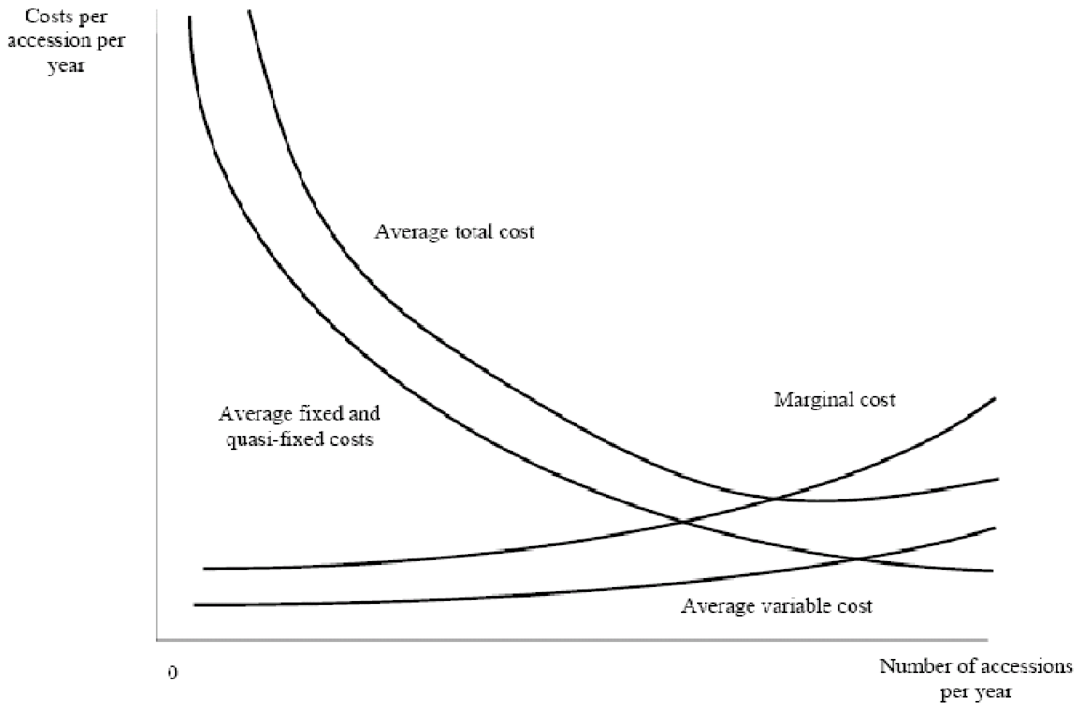
The data compiled by genebank managers on input use and expenditures was used to estimate average and marginal cost per unit. Average costs are the costs for the genebank of managing one accession. Marginal costs are the increase in total costs from the addition of one more accession to the genebank. Total costs include costs that vary and costs that are fixed in the relevant range of production. Average fixed or quasi-fixed (genebank management) costs normally decline as output increases. A standard assumption of micro-economic theory is that marginal costs initially decline as more is produced in a plant and eventually increase due to diminishing marginal returns to fixed factors (e.g., land, plant). Marginal cost is equal to average total costs when average total cost is at a minimum. Notice however that often genebanks operate below capacity, average costs then represent only upper bounds estimates of the marginal costs. Figure 2.1 illustrates how average and marginal costs are thought to change with amounts produced (for example, the number of seeds stored, regenerated, disseminated, etc).[4]

The research summarized in Koo *et al.* (2004) represents only a single year of data for 5 CG Centers. In order to evaluate genebank costs more generally a broader cross-section and longer time series is vital. Unfortunately, genebank operation costs have not been systematically recorded in the CG system. This information must be gathered in a uniform and systematic way in order to facilitate comparison across genetic materials and across centers. The use of the data management tool could facilitate a periodic data

[4] A few other studies have addressed the issue of cost implication of germplasm conservation, but without an explicit micro-economic framework. For example, Virchow (2003; 1999) used surveys to collect national conservation expenditure for 39 countries and estimated per-accession cost of annual conservation for each country. Burstin *et al.* (1997) also used surveys, examining the cost associated with sexually and vegetatively propagated species in several French genebanks. The authors calculated the annual and long term costs of each operation. Survey-based studies often suffer of inconsistent responses and excessive aggregation.

collection of input use and genebank expenditures related to operations and genetic materials manipulated. Managers can use this information to monitor and evaluate their performance, but also as input into strategic organizational decisions.

Figure 2.1. Genebank average and marginal cost



Source: Pardey *et al.* 2001.

3. Decision Support Tool

Genebank managers' decisions are often linked to the use of scarce resources in the most efficient and effective way. The **Decision Support Tool** is a excel file created to store genebank cost information and at the same time produce some reports and information that can guide genebank managers to make key management decisions. This decision support tool has been developed based on the framework of Koo *et al.* (2004). The first purpose of the tool is to store detailed input use per operation and generate cost reports.

The tool has been developed as an excel file with an introduction sheet, a general information sheet, 4 input sheets (non-labor variable, labor variable, quasi-fixed labor and capital inputs) and 3output sheets or reports. The introductory sheet provides a brief explanation of the purpose of the tool and the framework used to classify activities, inputs and costs. The general information sheet elicits details about the genebank (e.g., genetic material, number of accession managed, etc.) and other factors that affect costs (e.g., discount factor, overhead rate, period for performing operations).

Detailed **input** use and related expenses are entered in the decision tool, dividing the information by type of input (the categories are capital, labor and non-labor). In general, capital inputs are not as sensitive to the size of the operation. It is true for instance that the size of the cold store is linked to the numbers of accessions stored, or that the size of the tractor is linked to the number and size of plots, again linked to the number of accessions in the field. However changes occur only when the size of operations varies considerably. Capital inputs include infrastructure, such as germplasm storage and genebank facilities, and equipment for field operations and offices. The information entered includes the item, costs and year of acquisition. The value of the capital input is annualized using a discount factor. The value of the capital input can either be the actual value or the replacement value. The use of the replacement value is the preferable practice. When it is not possible to use the replacement value, the use of consumer price index (CPI) is standard practice to bring the value of the year of acquisition to current values.

Variable inputs, on the other hand, are sensitive to size of the operation. Variable inputs include non-labor costs and some labor costs. Non-labor variable costs mainly include inputs or supplies consumed on a regular basis, like energy, office and laboratory supplies. Note that the total costs of supplies consumed per year could be easily underestimated. Often, the financial systems in the CG centers record supplies demand using the number of requisitions over the year. This however is not the best alternative to estimate actual costs since often the genebanks order amounts higher than amounts actually used over the year. The best way to estimate these costs is by developing small budgets with the people in charge of each operation. Usually these supplies use can be related to the number of accession manipulated per operation per year. The information about capital cost was collected and annualized in order to have a complete picture of the genebank needs. Therefore, quite often not all the supplies used can be accounted with this procedure, resulting in lower calculate costs.

The information about variable labor costs corresponds to salaries paid to temporary workers and non-senior staff. This information is easily available through the financial system in each genebank. Senior scientists and technicians are treated as quasi-fixed labor or inputs. Quasi-fixed inputs are more variable than fixed capital inputs but unlike variable costs, they are not easily apportioned when the size of the operation changes. TO give an example, each genebank needs at least a regeneration expert independently of the number of accession multiplied in the field each year. However, if the number of accessions increases dramatically there might be a need to increase the staff.

All inputs used and expenses must be allocated by operation using rates. For instance, the total energy consumption in a genebank must be distributed among all operations that required energy. Allocation requires expert knowledge about the demands of genebank operations. Genebank managers thus are the persons who, in consultation with their staff, are most able to provide good estimates of allocation rates. Information about inputs is used to determine capital costs, quasi-fixed cost, variable costs, and genebank total costs. Allocation rates disaggregate these costs per operation.

To produce **output reports,** total costs are broken down into capital, variable, and quasi-fixed costs. In addition to a summary overview by crop and input costs, three kinds of output reports can be generated. The main report presents costs per input category, genetic material, and operation. The report provides information about both total costs and average costs per accession. The report also includes a graphic representation of the distribution of total costs. In the current version of the tool, this graph depicts the distribution of costs per input type, but other graphs could be developed based on expressed needs of genebank managers.

The DST has the potential to produce different types of output reports according to users' needs[5]. Two other examples are: 1) a per accession costs report of conservation and distribution, and 2) a total annual and in-perpetuity costs of conserving and distributing all existing accessions in the genebank. The first report summarizes annual and in-perpetuity average cost per accession classified in terms of either conservation or

[5] During the development phase of the DST genebank managers were consulted about potential new output reports that might be useful in their decision process.

distribution costs. Acquisition, viability testing, duplication, storage, and regeneration are operations that need to be performed in order to conserve an accession. Characterization, storage, regeneration, and dissemination are operations that are necessary in order to be able to distribute an accession. Costs are estimated for both new accessions and existing accessions, to indicate the additional cost of acquiring new accessions as compared to managing current accessions. The second report presents distribution and conservation costs associated with maintaining all existing genebank accessions. In this analysis, distribution costs are treated as short-run costs and conservation costs are considered to be “long-run” costs. This report shows the annual and in-perpetuity costs for the genebank. Such information is useful when justifying genebank funding or investment in ex-situ conservation.

While these reports help to understand the structure of genebank costs and their distribution across operations, objectives and over time, nothing can be inferred about the factors that affect these costs. For this reason, although it is possible to compare reports across genebanks, we do not have a picture that enables us to tackle strategic decisions.

4. Further Analysis

Two feasible ways to extend the use of the tool and the costs information collected are the use of sensitivity analysis with simulations and the evaluation of the genebank costs function.

4.1 Sensitivity Analysis with Simulations

When it is augmented by sensitivity analysis and simulations, the decision tool can be used to investigate how genebank costs and genebank performance are affected by changes in key parameters. An impediment to analyzing genebank costs across centers is the limited information that is available for statistical analysis. Genebanks have provided all information available about resources use and thus expenses on a particular year, we count with one and on best case with 3 years of information. This is rather a low number of observations. One way to overcome this impediment is to elicit a range of possible values for key factors from genebank managers. For instance, a statistical distribution of annual costs per accession, or in-perpetuity cost of conserving all accessions, could be generated based on elicited values.

The @Risk™ software can be used to define or adjust distributions to available data and to perform the sensitivity analysis. The software allows for the substitution of single point values with a probability distribution. A triangular distribution is the simplest distribution to elicit that approximates a normal distribution. This distribution is widely used in decision theory, especially when no sample data are available (Hardaker *et al.* 1997). The parameters defining the distribution are lowest, highest and most common value. Means, variances and coefficients of variation are easily tabulated from these three values, and repeated sampling from the distributions can be used to generate overall distributions.

For instance, let us take the number-of-accessions-regenerated-per-year (NREG) as an example of a factor affecting costs in a genebank. We can ask the genebank manager for information about the highest, lowest and most common values for NREG conditional on a reference period and technology. Using these three parameters, the software then generates a distribution of values for NREG. We could also generate unconditional distributions across technologies. Instead of a single value for total costs of maintaining a rice accession in the genebank, we would then have a distribution of values. The software can evaluate the simultaneous effect of more than one factor (input variable) on one or more than one cost variable (output variable).

In the decision tool, factors affecting genebank costs are currently included in the "general information" sheet. Preliminary simulations have been run based on this information. The long term goal of this cost collection exercise is however to evaluate the relationship between performance and costs and support genebank managers in their decision process. The framework proposed here would allow managers to discern how they might improve performance through re-allocating resources, or how they might maintain performance despite budget constraints. The availability of several years of information will probably facilitate this task. The initial challenge will be to make the right assumptions about the links among performance indicators, input use and costs. These links might not be as intuitive as expected. The variation in life cycle of the different operations conducted in the genebank, the share of resources allocated by genetic material, activity and/or operation diffuse the effect of input use on performance, making it difficult to isolate and establish causal relationships.

4.2 Costs Function

What would be the costs of reaching a "best practice" in the CG genebank system? How do location-specific variables affect genebanks costs? Genebank management decisions and their costs implications need to be evaluated to improve the performance of individual genebanks but also of the system as a whole. The second, longer-term objective the decision support tool is to provide answers to questions about the global genebank system. When enough observations have been assembled through application of the decision support tool, a genebank cost function can be estimated and specific hypotheses tested.

Genebanks costs depend on several factors: biological characteristics of the crop conserved, conservation methodology used (in vitro, field germplasm banks), institutional differences (wage structure, cost-sharing opportunities), local climate (for regeneration for instance, general state of infrastructure). The use of econometric methods will permit SGRP to evaluate the system as a whole by disaggregating the effect of the different factors and performance grade on costs. Once these effects have been taken into account in a multivariate regression, it will be feasible to draw conclusions across centers and genetic materials.

Cost function approaches have been used to model other public goods like hospitals and libraries, and this literature can provide insights into how we might specify genebanks costs. Finch and Christianson (1981) modeled the costs function of rural hospitals in US. The purpose of their study was to supply information about hospital costs that be used in making decisions regarding how the provision of health care to rural populations. The authors used quadratic and logistic specifications. The main advantage of the quadratic U-shape function is that a cost minimum can be determined given a fixed level of output. The logistic L-shape cost function implies that costs are decreasing but not in a constant rate to output, similar to what we assumed for genebanks. An additional contribution of this study is the use of output indicators to account for short run and long run costs. Conservation and distribution of genetic materials and information fit this characterization well.

Liu (2002) modeled a cost function for academic research libraries, taking into account the multi-product and multi-service nature of information provision by such organizations, which is comparable to genebanks. The author used a log-linear function and considered that some economies of scale exist in the operation of research libraries. Translog cost models have been also used for evaluating the costs function of research libraries. The use of a translog cost function is convenient when the goal is to determine elasticities of substitution among different inputs. De Boer (1992) used a translog cost function to examine economies of scale and input substitution elasticities of 194 Indiana public libraries.

If the objective of modeling genebank costs is to evaluate the relationship between cost and outputs with current technology and practices, logistic or quadratic specifications suit the purpose. If the objective is however to determine a technical relationship among inputs and outputs, a translog model would do better. It is always possible to test different specifications and evaluate which one adjusts better to our needs.

In specifying the model it is also important to define which cost to model: total costs or average (variable) cost. Modeling total costs would provide some additional information on capital and quasi-fixed costs. Since it is expected that changes in technology (mainly capital inputs) would improve performance of specific activities and operations, it may be better to model total costs than average variable costs. It is also possible to model total cost per operation.

Exogenous variables will include performance indicators for each output, a vector of crop characteristics, a vector of genebank characteristics, and a vector of staff characteristics. Genebank objectives can be classified according to either short or long term goals. This classification would help to determine short- and long-term minimum costs. Outputs related to conservation (covering genepool, maintaining genetic integrity and ensuring security) can be considered of a long-term nature while outputs of germplasm use (ensuring availability, providing information and germplasm distribution) are considered to be short-term outputs.

The general function could then be specified as:

$$TC = f\left(PI, Cr, Gb, St, L\right)$$

Where

PI = performance indicators (for either short of long term goals),
Cr = crop characteristics (multiplication strategy, fertilization, etc),
Gb = genebank characteristics (facilities, equipment),
St = staff characteristics (number, skills); and
L = location (dummies).

The selection of appropriate performance indicators is crucial. Conservation indicators might include the number of accessions stored, or indicators of diversity represented by the accessions. Indicators for use of germplasm might be the number of accessions added per year, the number of accession distributed, or the number of users of the genebank. Notice that the number of accessions added reflects the performance of genebank (technical operations) directly, while the other two indicators are related more directly to users and might be more appropriate if the goal is to measure the impact of a genebank.

The vector of crop characteristics includes the type of fertilization (open pollination, cross pollination) and type of seed reproduction system (sexual or vegetative). Differences in crops and reproduction system have a definitive effect on the costs. Genebank characteristics that can influence the cost function are related to the type of equipment and facilities. This information is also valuable to determine if the genebank is operating under excess capacity or not, and thus where economies of scale might be achieved. Staff characteristics variables can help to explain the effect on costs of staff qualification and the number of staff working in the genebank. The use of dummy variables is recommended to factor out location specific effects.

SECTION 3

Conservation and Management of Genetic Resources of Beans, Cassava and Tropical Forages in the CIAT Genebank

D. Horna, D. Debouck, A. Ciprian, M. Cuervo, R. Escobar, A. Hernandez, G. Mafla, C. Ocampo, L.G. Santos, O. Toro

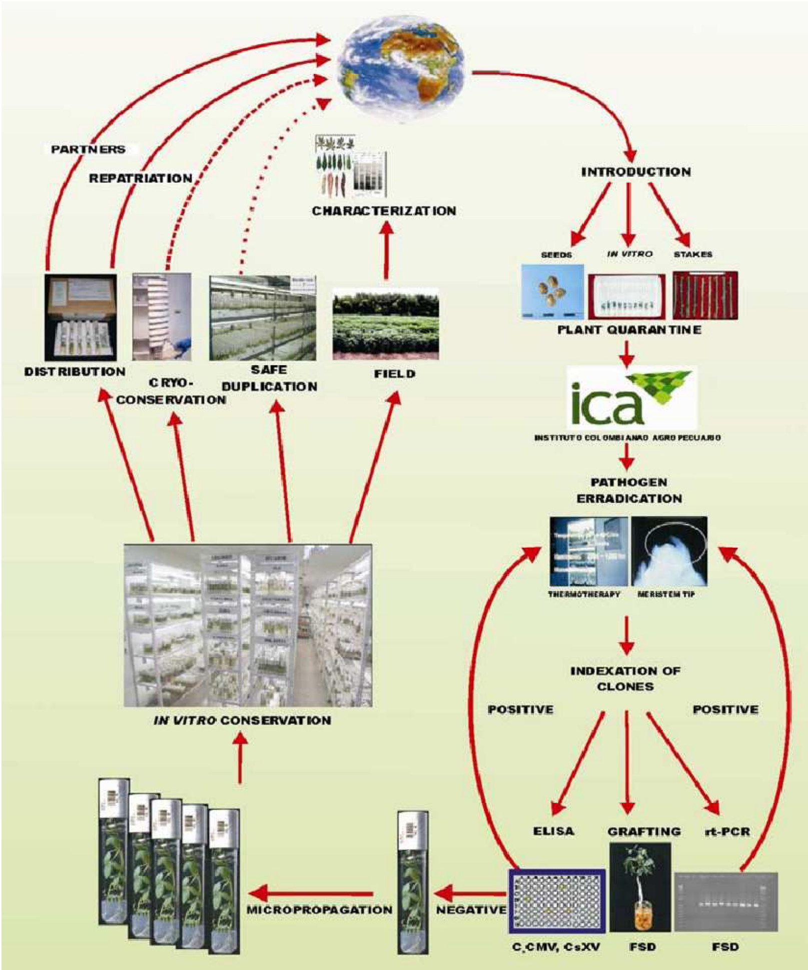
The genebank at CIAT currently holds germplasm of cassava, beans and tropical forages. Note that beans and cassava are Annex1 crops covered under the multilateral system of the International Treaty on Plant Genetic Resources for Food and Agriculture (FAO 2002). All the three collections are unique. Furthermore the collection of beans and cassava at this genebank are the largest in the world. In the case of beans it accounts for 15% of the total accessions in ex-situ conservation (Johnson *et al.* 2003).

Given the agronomic and regeneration differences across the three types of materials manipulated, this genebank have two flows of operations. Cassava as a clonal crop has to be stored and multiplied under in-vitro conditions. Beans and tropical forages are mainly seed propagated germplasm and their conservations and distribution followed standard protocols for this type of germplasm (Rao *et al.* 2006). Figure 3.1a and 3.1b presents both flows of operations within the CIAT genebank.

Costs analysis of CIAT' genebank have been documented in two previous studies. The first evaluation was carried out by Epperson *et al.* (1997), and concentrated on cassava. The second work was done by Koo *et al.* (2003) covering all materials and all genebank operations. Both studies use a similar framework, detailing on the different types of inputs use (capital labor) and estimating total and average costs of conservation. The work done by Koo *et al.* is however more complete as the costs are disaggregated by operations. This evaluation follows a similar framework, but provides more detailed information on other actual costs. Additionally, the information has been collected using a similar framework across CG genebanks. General management and information management costs have been taken apart from the costs of the other operations.

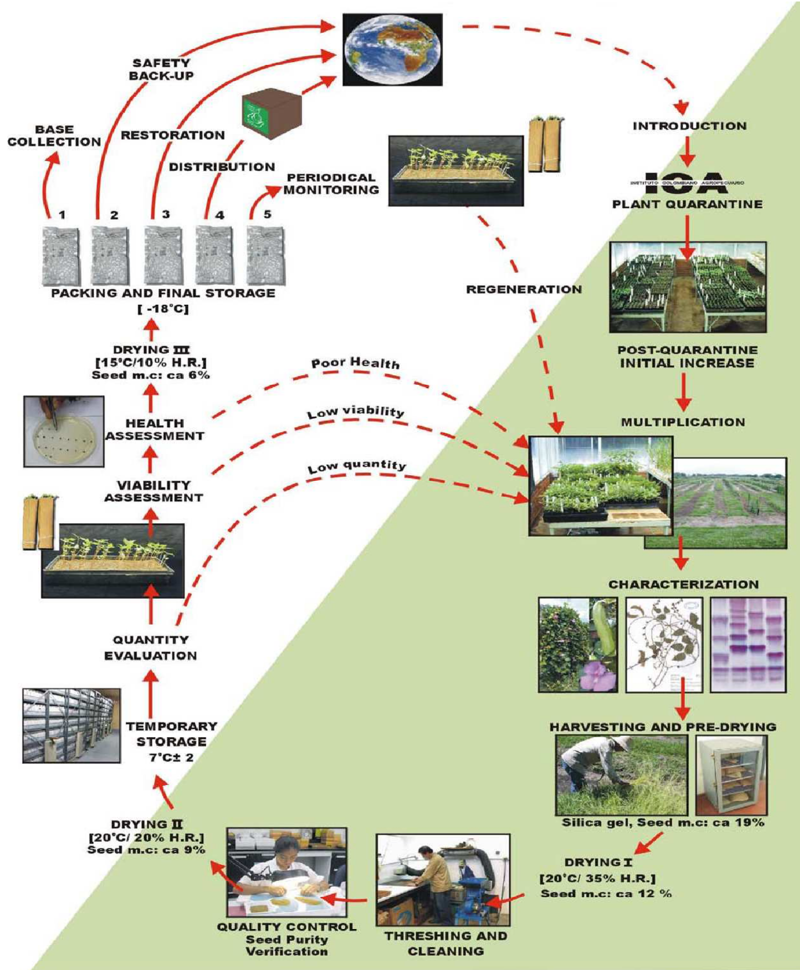
Figure 3.1. Flow chart for germplasm management in the CIAT genebank

a) Cassava



Source: Mafla *et al.* 2008

b) Beans and Tropical Forages



Source: Salcedo *et al.* 2006

3.1. Data

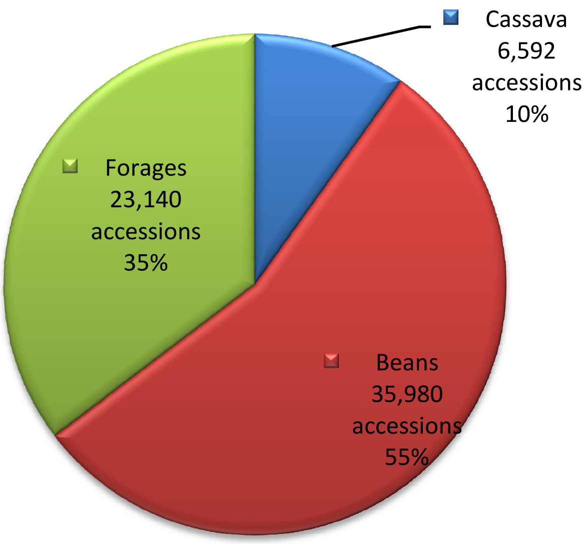
The evaluation of CIAT genebank cost corresponds to the years 2006, 2007 and 2008. By 31 December 2009 this genebank had approximately 65,000 accessions designated and duly registered to the International Treaty. From this total more than 35,980 are accessions of beans, 23,140 of tropical forages, and 6,592 of cassava (Figure 3.2). The use of the DST allowed the collection of detailed information on the use of capital (equipment and facilities), and non-capital inputs (labor and supplies). The total costs estimated with the DST are actual annual costs given a budget constraint. Capital and quasi-fixed input information was provided by CIAT financial services. CIAT genebank own records were used to complete the information on other inputs use like labor, and field, office and lab supplies. As explained in the previous section the data collected on variable inputs used and costs derived from this data might suffer from a downward bias as it is difficult for the genebank staff to account for every item used in each operation.

Testing for Frog Skin Disease

Recently CIAT has developed a new methodology for testing the Frog Skin disease (FSD) by introducing molecular techniques. This disease is supposed to be caused by a virus transmitted by a vector, most likely an insect. This is the most important cassava disease in Colombia. It can cause up to 90% of damage because it attacks roots and does not allow for starch accumulation. The classical test for the presence of FSD was to graft a hypersensitive cassava clone (Secundina) on the material to be tested. Secundina expresses a very strong mosaic in the leaves when infected by FSD. The material to be tested is made of the stem plus a root system. The aerial part will be made of the hypersensitive clone. This new testing method has not only the potential to reduce costs but also time to process samples and obtain results. With the grafting technique the test could take up to 21 weeks since the cassava plants have to be grown up in the greenhouse and then grafted with the susceptible plant. Moreover not all of the genebank accessions are able to be grown up in the greenhouse, so this test cannot be performed in all accessions. The current method use is a Reverse Transcriptase-PCR. The test takes only 5 days. Currently most of the genebank accessions have been tested.

M. Cuervo, D. Debouck

Figure 3.2. Accessions at the C Genebank according to type of material



3.2. Results

Reports of total and average costs per operation are presented in Tables 3.1 – 3.3 for 2008.[6] For cassava, the most expensive operation is the molecular characterization (US$ 108 per accession). This operation although not considered a custodianship operation can help to significantly reduced operational costs in the genebank as it allows the identification of duplicates. Cryopreservation is also an operation that currently show a high average cost but this is mainly due to the low number of accession currently conserved under cryo conditions. Cryopreservation is still an operation under research and evaluation in the genebank. Cassava material is currently conserved and safety duplicated in-vitro. The annual average costs of in-vitro (US$ 14.28) seem to be considerably lower than the average costs of cryopreservation (US$ 44.22), but the long term costs are considerably higher in the case of in-vitro. Seed health testing[7] is a well a relatively expensive operation (US$ 46). The in-vitro material has to be carefully monitored and tested for a number of viral infections before it is accessed to the genebank or distributed to other

[6] Information for 2006 and 2007 is also available.
[7] We use the generic term seed to refer to the propagating material in general. Cassava is multiplied and conserved in-vitro.

countries.[8] Nevertheless these costs would probably decrease in the future as CIAT has developed a new methodology to test one of the viral diseases, the frog skin disease (FSD). Distribution costs of cassava material are as well considerably expensive for the genebank as each accession has to be multiplied in vitro and send under special conditions to the final users. There were no new cassava materials acquired or characterized by the genebank in 2008. It is important to point out that acquisition is a long process that begins with the reception of the material and ends with their designation to FAO. In this process the materials are evaluated to make sure that they are clean of pathogens (seed health testing) and they are unique (molecular characterization to detect duplicates). These operations can happen well in advance the accession is finally entered into the system (acquired). These lags have implication on the accounting of costs. For instance in 2009 125 cassava accessions were acquired (designated) meaning that the evaluation and characterization was performed in 2008.

For beans the most expensive operation in 2008 was seed health testing (US$ 37 per accession). As in the case of cassava, all incoming and outgoing accessions have to be tested for a number of viral diseases, but also for seed borne fungal and bacterial infections. The largest share of the seed health testing costs is the laboratory supplies, mainly the kit sets for evaluating diseases. In 2008 around 4,700 bean accessions were screened. If this number would have been higher the average cost would have been lower. The number of accession tested however depends on several factors that can or cannot be under the control of the genebank. Under the genebank control is the number of accessions that can be processed giving the personnel available for this work. The number of accessions requested for distribution on the other hand is independent of the genebank and often difficult to predict.

In 2008 acquisition and characterization of bean accession also reported the high costs compare to the other operations. In the case of acquisition (US$ 26) the relatively high cost was due to the few accessions manipulated.[9] Characterizations (US$ 26) together with regeneration (US$ 24) are often resource intensive operations for materials that are

[8] Since the cassava collection is an in-vitro collection there is no risk of fungal and bacterial infections.
[9] The actual costs of acquisition are probably a bit higher than reported in this Table 3.2. When a new accession is acquired it has to pass a quarantine process. Most of these costs would be qualified as variable costs.

propagated by seeds. Storage, temporary and long term, requires some capital investment but the most important cost component is energy. As a consequence when more accession are added to storage the lower the average costs of this operation.

In the case of forages regeneration (US$ 87) and characterization (US$ 46) recorded the highest averages costs in 2008. This is rather expected since many of the tropical forages accessions are wild materials that require special field and agronomic conditions to generate seed. In other words, not all the materials that are planted this year would produce seed or be characterized (see Annex 3). Seed health testing (US$ 43) as well as seed processing (US$ 34) short term storage (US$ 34) also record high average costs. Seed processing is an operation that involves a number of activities before planting for regeneration and characterization and after harvest and before storage. Tropical forages are quite distinctive species with quite distinctive seed. Selection and cleaning of these seeds is a labor intensive activity. There was no acquisition of tropical forages in 2008.

The possibility of collecting several years of information allowed having an idea of CIAT genebank performance over the period evaluated (2006-08). Figures 3.3 – 3.5 represent the changes in total and average costs over the period 2006-2008. It is important to mention that the use of total and average costs is relevant for time series analysis but these figures could hide information that can explain the genebank performance over the years. For example, expenditures on forages in 2006 were considerably lower than in consecutive years. This was probably due to internal CIAT financial developments. This tendency is not evident on cassava or beans, probably because of the Annex 1 status of these crops and the need to have materials available to users. In any case, this is clear evidence on the experience of genebank managers and experts in deciding the best practices to implement when (budget) constraints arise. An average cost of regeneration of forages was particularly low in 2006. Average costs are estimated using total expenditures and the total number of accessions manipulated. Evidently the average costs during 2006 were lower than in later years. This however can have some implications on the quality of the expected outputs. Note that in the case of regeneration we have the number of accessions processed, but not number of accessions that produced enough material to be stored, distributed and evaluated per year.

Table 3.1. Operational Costs of CIAT Genebank: CASSAVA - 2008

Activities	No. access.	Total capital cost **(US$)**	Total quasi-fixed cost **(US$)**	Total labor variable costs **(US$)**	Total non-labor costs **(US$)**	Average capital cost **(US$/acce.)**	Average quasi-fixed cost **(US$/acce.)**	Average variable labor cost * **(US$/acce.)**	Average non-labor costs **(US$/acce.)**	Total AC**
Acquisition	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Characterization	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Safety duplication	2,119	12,075.81	23,377.97	0.00	6,181.74	5.70	11.03	0.00	2.92	13.95
Cryo-preservation	640	1,992.33	9,938.12	0.00	18,364.16	3.11	15.53	0.00	28.69	44.22
In-vitro conservation	8,261	14,337.36	70,137.48	0.00	47,864.97	1.74	8.49	0.00	5.79	14.28
Seed health testing	597	10,396.20	4,819.16	0.00	23,022.19	17.41	8.07	0.00	38.56	46.64
Distribution	1,348	2,552.52	21,218.39	0.00	7,500.87	1.89	15.74	0.00	5.56	21.31
Information management	6,467	7,911.04	7,526.81	0.00	2,402.83	1.22	1.16	0.00	0.37	1.54
General management	6,467	4,969.39	6,776.22	0.00	2,095.90	0.77	1.05	0.00	0.32	1.37
Bioche. & Mol. Character.	233	6,777.49	25,180.32	0.00	0.00	29.09	108.07	0.00	0.00	108.07
Total* **	**N.A.**	**61,012.13**	**174,905.32**	**0.00**	**107,432.66**	**60.93**	**169.15**	**0.00**	**82.23**	**251.37**

(*) There was no report about temporary labor (ETA).
(**) Operational costs, do not include capital costs.
(***) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 3.2. Operational Costs of CIAT Genebank: BEANS - 2008

Activities	No. access.	Total capital cost **(US$)**	Total quasi-fixed cost **(US$)**	Total labor variable costs **(US$)**	Total non-labor costs **(US$)**	Average capital cost **(US$/acce.)**	Average quasi-fixed cost **(US$/acce.)**	Average variable labor cost **(US$/acce.)**	Average non-labor costs **(US$/acce.)**	Total AC
Acquisition	255	0.00	6,024.72	0.00	721.84	0.00	23.63	0.00	2.83	26.46
Characterization	3,041	17,312.38	70,378.65	1,160.45	9,788.10	5.69	23.14	0.38	3.22	26.74
Safety duplication	24,241	1,248.66	10,520.68	0.00	10,054.70	0.05	0.43	0.00	0.41	0.85
Long term storage	2,539	431.44	11,879.86	5,179.68	19,435.56	0.17	4.68	2.04	7.65	14.37
Medium term storage	2,645	4,152.11	10,731.94	0.00	27,743.69	1.57	4.06	0.00	10.49	14.55
Germination testing	4,827	11,556.24	12,521.86	0.00	9,079.83	2.39	2.59	0.00	1.88	4.48
Regeneration	3,041	16,335.49	63,733.26	1,160.45	10,094.59	5.37	20.96	0.38	3.32	24.66
Seed processing	5,140	9,737.96	70,861.28	5,179.68	24,599.27	1.89	13.79	1.01	4.79	19.58
Seed health testing	4,713	27,329.93	54,749.94	0.00	123,300.41	5.80	11.62	0.00	26.16	37.78
Distribution	2,500	1,248.66	7,071.79	5,179.68	4,341.46	0.50	2.83	2.07	1.74	6.64
Information and data management	35,903	1,914.25	64,100.76	0.00	16,818.35	0.05	1.79	0.00	0.47	2.25
General management	35,903	6,753.10	37,619.72	0.00	11,635.84	0.19	1.05	0.00	0.32	1.37
Biochemical & Molecular Characterization	2,046	5,286.46	12,204.00	0.00	0.00	2.58	5.96	0.00	0.00	5.96
Total	**N.A.**	**103,306.68**	**432,398.47**	**17,859.95**	**267,613.66**	**26.27**	**116.52**	**5.88**	**63.29**	**185.69**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 3.3. Operational Costs of CIAT Genebank: TROPICAL FORAGES - 2008

Activities	No. access.	Total capital cost **(US$)**	Total quasi-fixed cost **(US$)**	Total labor variable costs **(US$)**	Total non-labor costs **(US$)**	Average capital cost **(US$/acce.)**	Average quasi-fixed cost **(US$/acce.)**	Average variable labor cost **(US$/acce.)**	Average non-labor costs **(US$/acce.)**	Total AC
Acquisition	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Characterization	2,069	11,281.17	6,600.17	31,551.69	58,302.53	5.45	3.19	15.25	28.18	46.62
Safety duplication	10,307	2,403.07	5,094.07	0.00	4,319.22	0.23	0.49	0.00	0.42	0.91
Long term storage	2,140	3,913.01	10,662.14	5,179.68	16,289.79	1.83	4.98	2.42	7.61	15.01
Medium term storage	216	4,152.11	4,670.06	0.00	2,789.85	19.22	21.62	0.00	12.92	34.54
Germination testing	1,728	7,019.99	12,521.86	0.00	4,474.84	4.06	7.25	0.00	2.59	9.84
Regeneration	1,746	11,458.70	63,546.16	31,551.69	57,996.04	6.56	36.40	18.07	33.22	87.68
Seed processing	3,084	16,664.44	47,014.26	25,898.40	32,454.60	5.40	15.24	8.40	10.52	34.17
Seed health testing	1,805	13,342.52	31,275.70	0.00	47,221.99	7.39	17.33	0.00	26.16	43.49
Distribution	235	2,403.07	3,110.95	5,179.68	798.88	10.23	13.24	22.04	3.40	38.68
Information and data management	23,140	2,831.74	48,986.40	0.00	10,045.99	0.12	2.12	0.00	0.43	2.55
General management	23,140	5,956.70	24,246.45	0.00	7,499.47	0.26	1.05	0.00	0.32	1.37
Total	**N.A.**	**81,426.53**	**257,728.23**	**99,361.14**	**242,193.19**	**60.76**	**122.90**	**66.18**	**125.78**	**314.86**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Figure 3.3. CASSAVA: Changes in Total and Average Costs per Operation over the Period 2006 – 2008 for CIAT Genebank

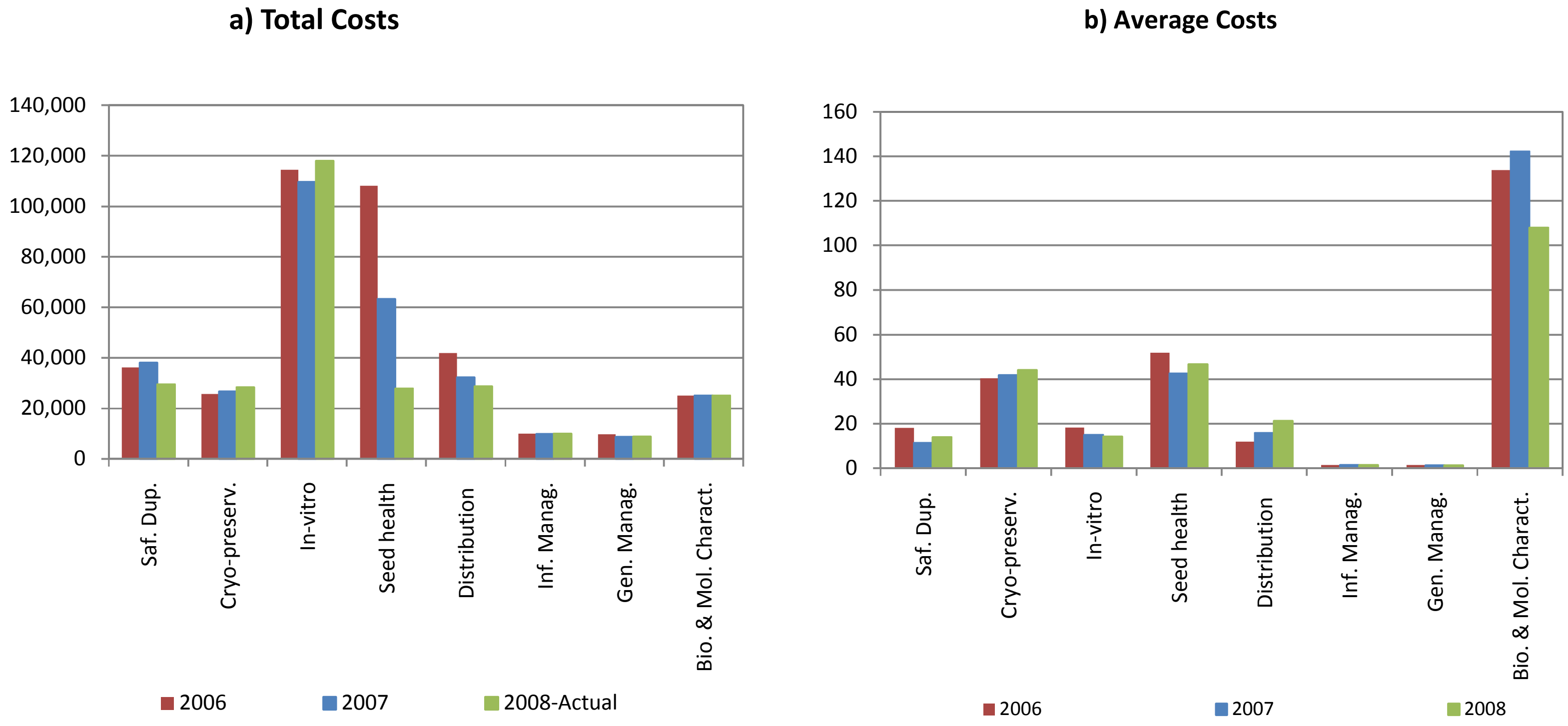


Figure 3.4. BEANS: Changes in Total and Average Costs per Operation over the Period 2006 – 2008 for CIAT Genebank

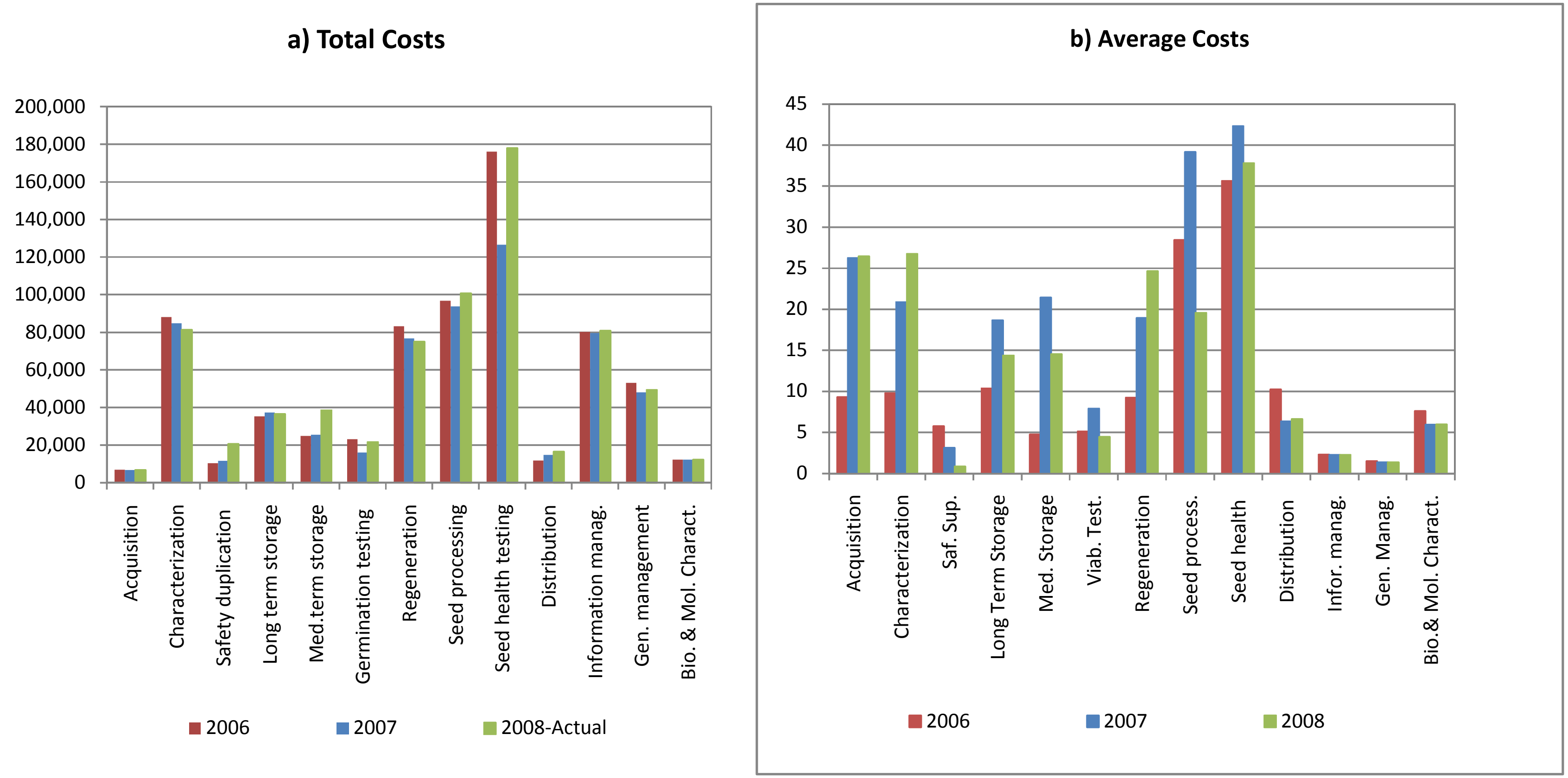
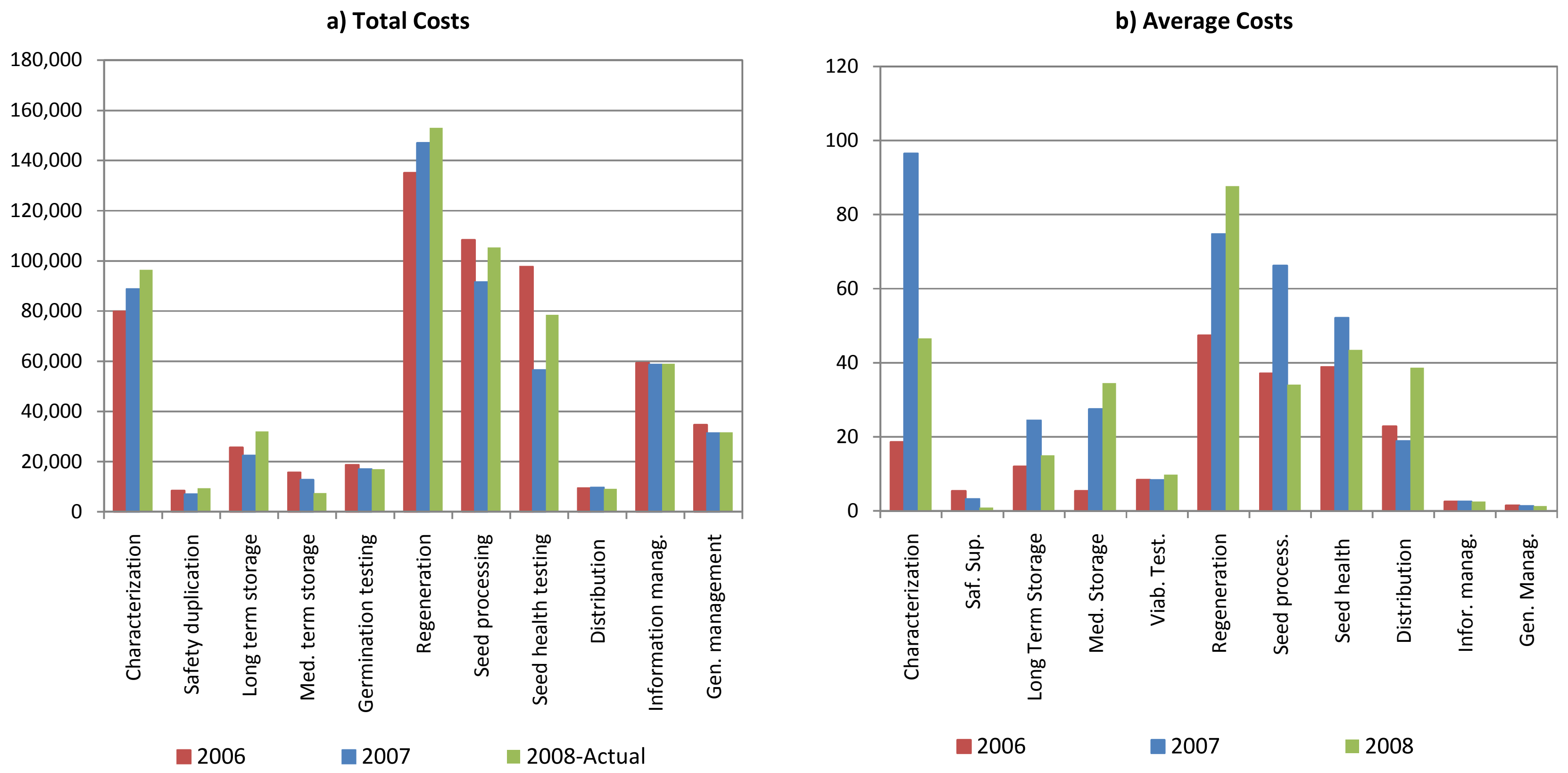


Figure 3.5. TROPICAL FORAGES: Changes in Total and Average Costs per Operation over the Period 2006 – 2008 for CIAT Genebank



SECTION 4

Conservation and Management of Maize and Wheat Genetic Resources in the CIMMYT Genebank

D. Horna, T. Payne, S. Taba, B. Espinoza, M. Rivas

CIMMYT genebank holds an impressive collection of almost 150,000 accessions of two important food security crops, wheat and maize. The current wheat collection is a mixture of advanced breeding lines and parental materials from the CIMMYT breeding programs, landrace collections from various regions, and materials provided y collections or breeding programs of other research agencies in other countries (Taba 2001). The maize collection is based on several collections efforts mainly in Latin America. The genebank also conserves accessions of barley and triticale, as well as other accession important o breeders like *Tripsacum sp.* and teosinte which is the closest relative to maize. This study and the reports prepared focuses on maize and wheat exclusively and only on custodianship operations. Both of these crops are seed propagated material. The CIMMYT genebank performance has been previously evaluated by Pardey *et al.* (2001, 2004).

With more than 120,000 accessions of wheat and about 27,000 accessions of maize, the main challenge for the genebank is to multiply and manipulate these accessions. While Mexico is a country with favorable conditions for the multiplication of wheat and maize, some agro-ecosystems favorable to multiplication of these crops are not necessarily represented in the country. Wheat for instance is cultivated from sea-level to 4,000 masl and from the equator to Norway. This environmental constraint has implications on the cost of regeneration of the material and on the overall flow of operations. Figure 4.1 presents the flow of operations in CIMMYT genebank.

The large number of wheat accessions the CIMMYT genebank suggest that the collection of the most important local landraces has been achieved (Taba el at. 2004). Given its polyploidy nature wheat has suffered several transformations. More recently, the use of biotechnology and cytogenetic tools has contributed to these transformations. The challenge for the wheat genebank collection is therefore to keep unlocking the latent diversity and make it available to the final users. It is important therefore to keep looking for efficient and cost-effective methods to identify these sources of diversity (varieties, traits, genes) that could help to deal with biotic or abiotic constraints. The collection of cost information could help in this task if the information collected includes in the future the impact related operations.

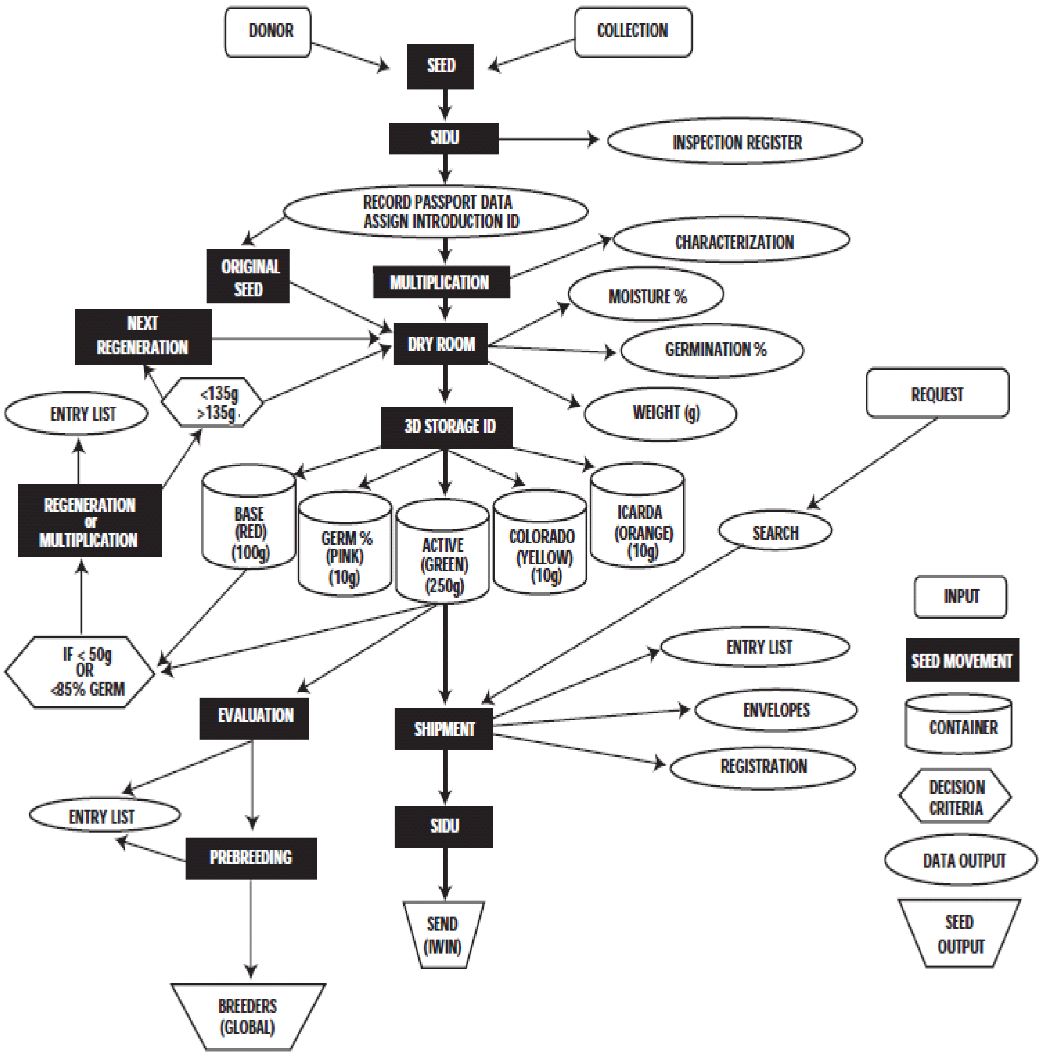
The maintenance of the genetic integrity of a cross pollinating crop like maize is a challenge for the genebanks dealing with these kind of materials. The CIMMYT genebank is in favor of in-situ conservation of maize and pre-breeding work ex-situ. According to CIMMYT staff, the pre-breeding is equivalent to the interest paid for storing the seeds. Maize genetic material kept *in-situ* (Mexico, Guatemala, Peru, etc.) is classified into races and they keep evolving. *Ex-situ* collections of maize, on the other hand are classified into populations where there is little room for changes over time. The evolution of the materials however is important and, as the genebank staff argues, it is better to think in conservation as a dynamic process rather than a static one. Therefore under ex-situ conditions materials can be characterized (with agronomic, molecular or biochemical procedures) and the coverage of the genepool can be verified but pre-breeding could be part of the routine operations of the genebank, as it is in the case of maize in CIMMYT. Unfortunately, in this study we did not collect specific information about pre-breeding costs as it is considered an impact-related operation. The DST however can be used to collect this information in the future.

4.1. Data

This evaluation has been done using cost information from 2007. Additional information was collected for 2008, but mainly on the number of accession manipulated. As of 2008 the genebank hold 27,187 accessions of maize and 122,189 accession of wheat, barley and triticale (Figure 4.2).As a consequence the total and average genebank costs of 2007 are accurate while the estimates for 2008 are best approximations. Note that there is probably a downward bias on the total costs estimation as the information about capital costs, mainly equipment, was incomplete. Still since the value of capital goods is annualized the impact on total and average cost of operations is not significantly affected.

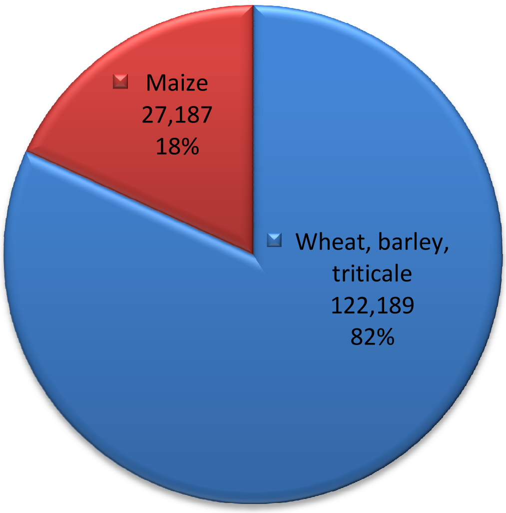
This is especially true in the case of the CIMMYT genebank as the manipulation of maize and wheat does not demand for high investment equipment.

Figure 4.1. Flow of Operations in the CIMMYT genebank (Wheat)



Small samples of seed are received and enter the germplasm bank (top of the flowchart). It is then checked for seed health by the Seed Inspection & Distribution Unit (SIDU), its passport data is registered in the database and it is assigned an accession ID. The seed is then multiplied to have sufficient seed to store and satisfy outside requests. The seed is dried to a low moisture level to increase its longevity, and five sub-samples are assigned 3D storage IDs that record the physical location of the seed in the gene bank. The five sub-samples are stored (i) in the active collection to satisfy client requests, (ii) in the very long-term storage area of the base collection; (iii) maintained for later germination tests, (iv) shipped as back-up seed to the National Center for Genetic Resources Preservation (NCGRP) in Fort Collins, Colorado, USA, and (v) shipped as back-up seed to ICARDA in Syria. After seed requests arrive and are documented, desired seed is taken from the active collection and processed for shipment. Finally the seed is sent to the requesting collaborator through the International Wheat Information Network (IWIN). Evaluation for specific traits and pre-breeding activities enhance the usefulness of the products that we make available to breeders worldwide. Regeneration takes place as seed quantity or germination percentage drop below set limits. At all levels data is generated and stored in a central database.
Source: Taba *et al.* 2004

Figure 4.2. Accessions hold at the CMMYT genebank by type of material



4.2. Results

Total and average costs per operation are presented in Tables 4.1 and 4.2 for wheat and maize. In general the CIMMYT genebank invest more resources in maize conservation than in wheat conservation. This is completely due to the pollination method of the crop. The conservation costs of wheat germplasm are affected mainly by the large number of accessions stored. In average terms however wheat tends to be a low maintenance crop. The operation with the highest average cost is acquisition (US$ 58) due mainly to fixed and quasi-fixed costs and also to the low number of accessions that are acquired per year. Given the large coverage of the genepool, acquisition of new materials is rather a small operation. Moreover, the costs estimations of total and average acquisition costs include the initial seed inspection and multiplication of materials.

In average terms, the most expensive operations for wheat are seed health testing (US$ 5.85) and viability or germination testing (US$ 6.19). Seed health is evaluated by the Seed Health Testing unit (SHT) of CIMMYT that works independently of the genebank and provides services to the whole institute. SHT has done estimations of the costs per accession and is currently charging fixed rates. This unit charges a constant fee of US$5 per sample of 10 accessions of wheat. In total costs terms regeneration and seed health testing require the largest investment for wheat conservation and management.

Regeneration is a core operation that procures having enough seed volumes for conservation but also for distribution. Seed health is expensive because it is an operation that has to be carried out every time there is a new introduction and most importantly every time the seed is distributed to third parties.

Safety duplication costs presented in table 4.1 correspond to 2007, we have used the total number of wheat accessions sent in 2008 to estimate the average costs and have added the costs of 2007 and 2007. Safety duplication requires some preparation before the materials are shipped to the safety storage place. Therefore there is a lag between sample preparation and actual shipment of the materials. Also note that characterization of wheat germplasm it is not a current operation for wheat germplasm at CIMMYT, therefore there are no costs recorded for this operation.

In the case of maize, the operations with the highest average costs are characterization (US$ 181.44) and regeneration (US$ 99.81). This was expected given the need to have controlled field conditions to be able to preserve the genetic integrity of an open pollinated crop like maize. Note that in average terms, the costs of characterization was higher than the costs of regeneration since the number of accessions regenerated was at least 3 times higher than the number of accession characterized in 2007. In absolute terms, the CIMMYT genebank invested more resources on regeneration (US$ 99,000) than in characterization (US$ 64,000). The difference was basically due to additional field expenses for regenerated materials that need to be harvested.

Seed health testing is 10 times more expensive for maize than it is for wheat, making this the third most expensive operation (US$ 50) in average terms, but the single most expensive operation in total costs. In 2007 the genebank invested around US$ 123,000 on seed health testing of 2,472 maize accessions. Seed processing (US$ 23.6), medium term storage (15.9) and acquisition (US$ 10.56) follow seed health testing in average costs.

There is a large discrepancy between the estimations done by Pardey *et al.* (2001) and the results of our estimations. Probable explanations for these discrepancies are:

- We are account for actual costs rather than genebank costs in an average year[10].

[10] Although, capital equipment is probably better accounted for by Pardey *et al.* (2004) as they have used replacement costs.

- We have separated the general management and information management costs from the other operations.
- Average costs in this study are estimating using the number of accessions manipulated the year of the evaluation. Pardey *et al.* (2001) used the total number of accessions in storage for similar estimations. This is particularly noteworthy for medium and long term storage.
- In the case of wheat, the main difference is due to acquisition costs. One explanation is that in 2000, when Pardey *et al.* performed their evaluation, there were around 5,800 new accessions of wheat acquired while in 2007 CIMMYT only acquired 209 wheat accessions. Furthermore, our estimations include also the costs of initial multiplication.
- In the case of maize the main difference is due to the addition of costs of characterization and seed health testing. In the Pardey et al evaluation characterization costs were included in regeneration costs. As explained above the SHT unit is now using a direct charge for their services.

Table 4.1. Operational Costs of CIMMYT Genebank: WHEAT – 2007

Activities	No. access.	Total capital cost **(US$)**	Total quasi-fixed cost **(US$)**	Total labor variable costs **(US$)**	Total non-labor costs **(US$)**	Average capital cost **(US$/acce.)**	Average quasi-fixed cost **(US$/acce.)**	Average variable labor cost **(US$/acce.)**	Average non-labor costs **(US$/acce.)**	Total AC*
Acquisition	209	245.37	10,701.13	308.84	1,423.72	**1.17**	**51.20**	**1.48**	**6.81**	**59.49**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	47,856	290	21,402	1,698.60	12,806.81	**0.01**	**0.45**	**0.04**	**0.27**	**0.75**
Long term storage	8,573	10,278.01	4,922.43	308.84	4,906.37	**1.20**	**0.57**	**0.04**	**0.27**	**0.88**
Medium term storage	8,573	11,737.04	4,922.43	308.84	4,367.04	**1.37**	**0.57**	**0.04**	**0.21**	**0.82**
Germination testing	1,000	3,359.23	2,884.96	617.67	2,789.65	**3.36**	**2.88**	**0.62**	**2.79**	**6.29**
Regeneration	30,449	6,292.89	12,991.52	12,353.44	41,677.88	**0.21**	**0.43**	**0.41**	**1.37**	**2.20**
Seed processing	60,692	4,841.63	16,285.50	9,265.08	2,773.82	**0.08**	**0.27**	**0.15**	**0.05**	**0.47**
Seed health testing	6,477	164.25	5,497.48	0.00	32,385.00	**0.03**	**0.85**	**0.00**	**5.00**	**5.85**
Distribution	5,411	164.25	10,600.61	6,176.72	4,969.19	**0.03**	**1.96**	**1.14**	**0.92**	**4.02**
Information management	121,980	24,003.57	117,793.75	617.67	2,857.04	**0.20**	**0.97**	**0.01**	**0.02**	**0.99**
General management	121,980	686.25	53,647.73	0.00	34,992.32	**0.01**	**0.44**	**0.00**	**0.29**	**0.73**
Total**	**N.A.**	**62,062.21**	**261,649.81**	**31,655.69**	**145,948.84**	**7.65**	**60.59**	**3.91**	**17.99**	**82.49**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 4.2. Operational Costs of CIMMYT Genebank: MAIZE – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acce.)	Average quasi-fixed cost (US$/acce.)	Average variable labor cost (US$/acce.)	Average non-labor costs (US$/acce.)	Total AC*
Acquisition	972	328.50	8,433.91	426.81	1,401.51	**0.34**	**8.68**	**0.44**	**1.44**	**10.56**
Characterization	355	1,839.60	42,225.13	12,804.20	9,380.28	**5.18**	**118.94**	**36.07**	**26.42**	**181.44**
Safety duplication	12,886	328.50	7,860.48	1,280.42	12,595.68	**0.03**	**0.61**	**0.10**	**0.98**	**1.69**
Long term storage	972	9,485.81	1,464.67	426.81	4,022.70	**0.33**	**1.51**	**0.44**	**1.39**	**3.34**
Medium term storage	155	17,155.07	1,464.67	426.81	3,372.92	**1.16**	**9.45**	**2.75**	**3.78**	**15.99**
Germination testing	1,874	3,210.90	4,792.05	853.61	3,344.33	**1.71**	**2.56**	**0.46**	**1.78**	**4.80**
Regeneration	992	1,839.60	42,225.13	12,804.20	43,979.22	**1.85**	**42.57**	**12.91**	**44.33**	**99.81**
Seed processing	1,127	9,151.95	14,727.74	8,536.13	3,328.59	**8.12**	**13.07**	**7.57**	**2.95**	**23.60**
Seed health testing	2,472	0.00	0.00	0.00	148,320.00	**0.00**	**0.00**	**0.00**	**60.00**	**60.00**
Distribution	17,693	328.50	13,241.35	4,268.07	8,338.54	**0.02**	**0.75**	**0.24**	**0.47**	**1.46**
Information management	26,581	15,228.53	19,701.44	853.61	3,328.59	**0.57**	**0.74**	**0.03**	**0.13**	**0.90**
General management	26,581	850.50	27,336.67	0.00	41,990.79	**0.03**	**1.03**	**0.00**	**1.58**	**2.61**
Total**	**N.A.**	**59,747.46**	**223,863.24**	**42,680.66**	**283,403.15**	**19.35**	**199.90**	**61.01**	**145.26**	**406.17**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

SECTION 5

Conservation and Management of Genetic Resources of Sorghum, Pearl millet, Chickpea, Pigeonpea, Groundnut and other Small millets in the ICRISAT Genebank

D. Horna, H. D.Upadhyaya, D.V.S.S.R. Sastry, V.Gopal Reddy, Sube Singh, K.N. Reddy, and C.L.L. Gowda

ICRISAT operates as a system of genebanks with a main genebank located in Patancheru, (India) and other 3 genebanks located in Niamey (Niger), Nairobi (Kenya) and Bulawayo (Zimbabwe). Each of these genebanks perform all the regular operations and conserve and distribute accessions to users according to their location. In its active collection the ICRISAT genebank at Patancheru holds more than 119,000 accessions of sorghum, groundnut, chickpea, pigeonpea, pearl millet and six other small millets (finger millet, foxtail millet, barnyard millet, kodo millet, little millet and proso millet). In total the genebank conserves accession of 11 different crops that represent 70 – 80% of the available diversity (Upadhyaya *et al.* 2008). Additionally, accessions of groundnut and pearl millet are also stored at Niamey, accession of sorghum and pearl millet at Bulawayo, and accessions of sorghum, pigeon pea and chickpea at the Nairobi genebank (Koo *et al.* 2004). In this evaluation we have evaluated only the Patancheru genebank and the main genetic materials conserved in its facilities. [11] The only previous cost evaluation of the ICRISAT genebank corresponds to the work of Koo *et al.* (2004) that also concentrated on the accessions kept at Patancheru.

The establishment of the collection at Patancheru was based on donations from existing collections in India, USA, Puerto Rico, Iran, Lebanon, Mozambique, Tanzania, Uganda and Kenya among other countries, and on targeted collections ICRISAT efforts launched between 1974 and 1997 (Upadhyaya *et al.* 2008, Koo *et al.* 2004). The main management challenges in the Patancheru genebank are the number of accessions held and the wide variety of crops. The various genebank activities are depicted in Figure 5.1. This genebank

[11] Currently ICRISAT staff is working on the collection of information in the Nairobi genebank.

has one of the largest collections in the CG system. While most of the materials are seed propagated, there are also a number of wild materials that do not produce seed and need to be conserved and multiplied using special facilities. The collection includes landraces (82%), non-domesticated species (2%), advanced and old cultivars (1%), and breeding lines (15%).

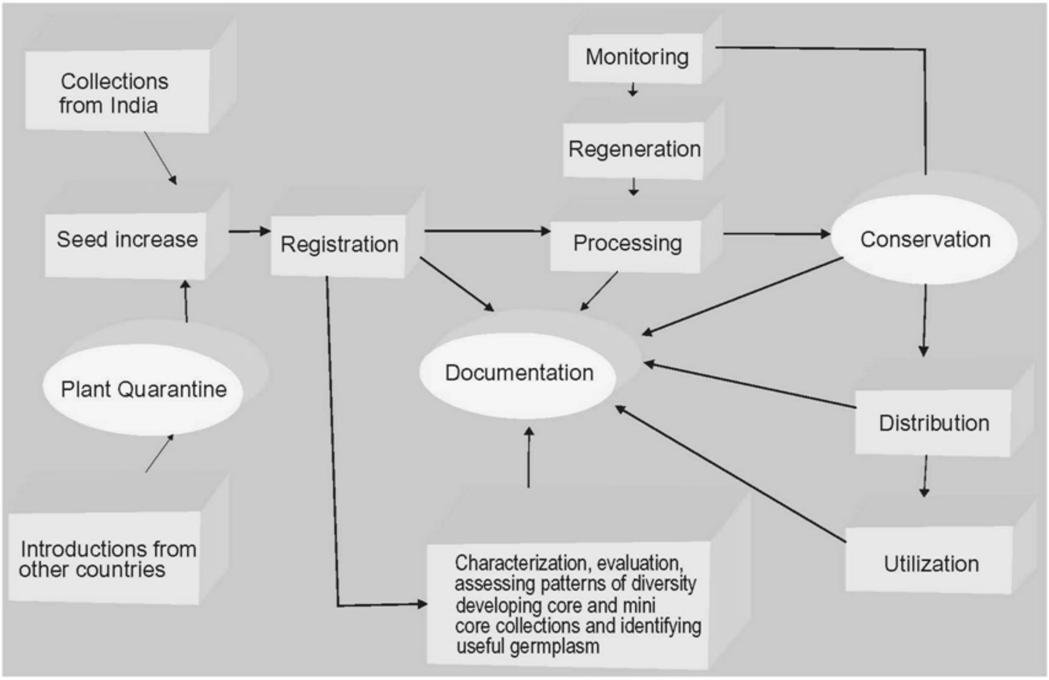
Several of the operations in the ICRISAT genebank are labor intensive. A clear example is seed processing of groundnuts that demands quantity and quality of labor. So far the cheap labor in India has helped to maintain the level of operations. We speculate that the increase in labor costs could be future constraint for the efficient management of genebank operations. The diversity of crops also adds to the complexity of the system and can have a potential impact on the aggregated costs, especially on the general management costs. The information collected can help to explore these hypotheses (see Section 9).

Another factor to take into account in this genebank is the aging of the scientific and technical staff. The replacement of experienced staff will definitively have an impact on the performance and cost of the operations. To avoid some of this potential negative impact the current practice at ICRISAT is to have overlapping training periods with outgoing and incoming staff. This practice has not been yet implemented at the genebank but the costs and benefits of implementing it can be easily be simulated using the current costs information available.

5.1. Data

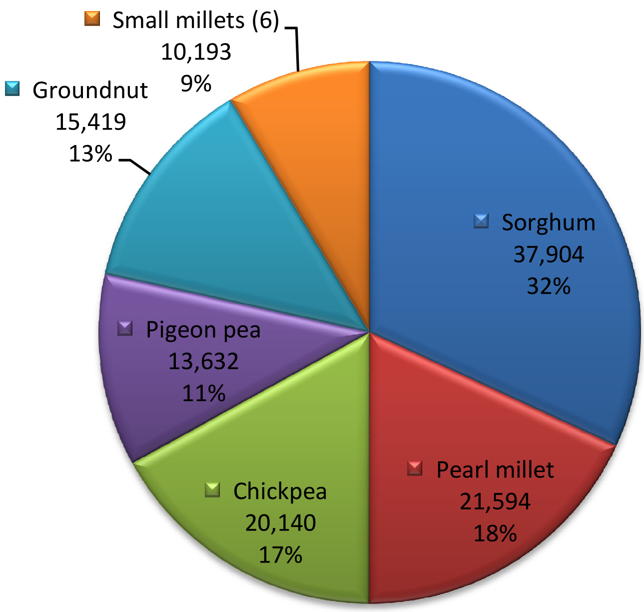
Detailed information on accessions manipulated, inputs use and related costs was collected for 2006 and 2007 for the six main types of crops conserved in the Patancheru genebank: chickpea, pigeon pea, groundnut, sorghum, pearl millet and small millets (Figure 5.2). We also collected information on numbers of accessions manipulated per operation for 2008. The best estimations of total and average costs per accession therefore correspond to 2006 and 2007. Note that each material has accessions that are cultivated and also wild accessions that require special conservation and multiplication facilities. The costs reported in this study include costs of these special facilities and inputs used for wild materials. Costs reports however are consolidated per type of material.

Figure 5.1. Operational flow chart of ICRISAT genebank activities.



Source: Upadhyaya personal communication

Figure 5.2. Accessions held by the ICRISAT genebank by type of material



5.2. Results

The total and operational costs for 2007 of the Patancheru genebank are presented in Tables 5.1 to 5.6. Sorghum records the largest number of accessions conserved in this genebank. In 2007 the most expensive operation in average terms was the acquisition of new materials (US$80) followed by characterization (US$ 17) and distribution (US$ 17). As it has been mentioned several times the number of accessions manipulated in each operation has a great impact over the average costs. About 21 new accessions of sorghum were introduced to the system, while 521 were distributed to users. In terms of total costs however, the operation that required higher investment was general management (US$ 43,000) followed by characterization (US$ 41,000) and regeneration (US$ 28,000). The largest share of the general management and regeneration cost corresponds to the quasi-fixed inputs (qualified staff), while in the case of characterization the largest expense corresponds to variable costs mostly field supplies. In Patancheru, sorghum characterization occurs during the rainy and post-rainy season, while regeneration occurs only during the post-rainy season.

The second crop with the highest number of accession stored at Patancheru is pearl millet. Pearl millet is the sixth most important cereal world-wide and is the main food source in the poorest regions of India and the African continent[12]. This is a highly cross pollinated crop that requires special regeneration conditions to avoid genetic drift (Table 5.2). Thus average regeneration cost of pearl millet (US$ 60) tends to be higher than for the other crops. The second and third most expensive operations are acquisition (US$ 30) while distribution (US$ 25) due to the low number of accessions acquired and distributed in 2007. In total costs, characterization (US$ 37,000) and regeneration (US$ 47,000) demand more investment than the other operations.

Chickpea is the world's third most important food legume, cultivated mainly in Algeria, Ethiopia, Iran, India, Mexico, Morocco, Myanmar, Pakistan, Spain, Syria, Tanzania, Tunisia and Turkey. Chickpea ranks third in number of accessions held at the genebank with a large variation of different traits. In order to target better the users' needs and the distribution of materials ICRISAT genebank has developed core collection consisting of

[12] http://www.icrisat.org/newsite/what-we-do/crops/PearlMillet/Pearlmillet/coreMillet.htm

about 2,000 accessions (Upadhyaya *et al* 2001). As shown in Table 5.3, distribution on average costs US$ 16/accession (in 2007). The most expensive operations for this material are acquisition (US$ 45 per accession), characterization (US$ 39/accession) and regeneration (US$ 26/accession). These are typically expensive field operations that demand mobilization of resources. The largest cost component of these average costs are qualified labor and field supplies.

Pigeonpea is an important legume crop mostly produced in Asia, Africa, Latin America and the Caribbean region[13]. Similar to pearl millet, pigeonpea is an often cross pollinated crop (up to 40%) which has implication on total and average characterization and regenerations costs. Thus regeneration of pigeonpea was the most expensive operation in 2007 (US$ 60 / accession) followed by characterization (US$ 42.3 / accession). About 270 accessions of pigeonpea were distributed in 2007, leading to an average cost of almost US$ 19 per accession shipped. During this year there were no accession acquired, duplicated, added to long term storage, evaluated for germination or sent for seed health evaluation. In table 5.4 we report the total an average costs of longer storage and viability testing of 2006.

Groundnut is a self-pollinated crop that is mainly grown in developing countries in Asia and Africa (95.5% of total production). The crop is grown mostly by smallholder farmers under rain-fed conditions with limited inputs[14]. ICRISAT genebank at Patancheru holds around 15,000 accessions of cultivated and wild materials. The regeneration (US$ 53,000) and characterization (US$ 52,000) of these materials demand the highest investments compare to the other genebank operations performed on this crop. In 2007, there were no new groundnut accessions acquired by the genebank. This year a total of 117 accessions were distributed to user at an average cost of US$ 17.74/ accession. Adding an accession into long-term conservation also reported relatively high cost (US$ 11/ accession). This high cost is probably due to two main reasons: a) we used numbers of accession added the year of evaluation, and not total number of accession on long-term storage; and 2) in 2007, only pearl millet and groundnut accessions were added to long-

[13] http://www.icrisat.org/newsite/crop-pigeonpea.htm
[14] http://www.icrisat.org/newsite/crop-groundnut.htm

term storage, thus the variable costs, mainly electricity was allocated to only these two crops. These costs represent the total for cultivated and wild materials.

Patancheru genebank also holds an important collection other small millets, around 10,000 accessions. Finger millet, a self pollinating crop, is originally native to the Ethiopia and highly adaptable to higher elevations[15]. Foxtail millet regarded as a native of China, it is one of the world's oldest cultivated crops. This crop ranks second in the total world production of millets and provides food to millions of people, mainly on poor or marginal soils in southern Europe and in temperate, subtropical and tropical Asia[16]. Kodo millet was domesticated in India almost 3000 years ago. Kodo millet has a high nutritional value, with a protein content of 11% and very high fiber content[17]. Little millet was domesticated in India and shows resistance to adverse agro-climatic conditions[18]. Proso millet is considered a self-pollinated crop, but natural cross-pollination may occur. This millet generally matures between 60-90 days after planting and can be grown successfully in poor soil and hot dry weather[19]. Barnyard millet is the fastest growing of all millets and produces a crop in six weeks. It is grown in India, Japan and China as a substitute for rice when the paddy crop fails[20].

Given the different number of species the conservation of small millets is a challenging task. The costs associated to their conservation and maintenance are however comparable to the other types of material conserved in the Patancheru genebank. In 2007 the most expensive operation was acquisition (US$ 54 / accession), but only 43 new accessions were acquired. Characterization (US$ 20,000), regeneration (US$ 27,000) and safety duplication (US$ 25,000) demanded most of the conservation and management investment in 2007. As most of the other crops maintained in this genebank, the distribution of accessions of small millets is a relatively expensive operation (US$ 18 / sample). In 2007 about 337 accessions of small millets were sent to users around the world.

---

15 http://www.icrisat.org/newsite/crop-fingermillet.htm
16 http://www.icrisat.org/newsite/crop-foxtailmillet.htm
17 http://www.icrisat.org/newsite/crop-kodomillet.htm
18 http://www.icrisat.org/newsite/crop-littlemillet.htm
19 http://www.icrisat.org/newsite/crop-prosomillet.htm
20 http://www.icrisat.org/newsite/crop-barnyardmillet.htm

Molecular characterization: At ICRISAT molecular characterization of germplasm collections is an important activity. Core collections (10% of entire collection), mini core collections (10% of core or 1% of entire collection) are genotyped to study population structure, assess genetic diversity and to identify trait-specific genetically diverse accessions for use by the crop improvement scientists besides identifying duplicates in the collections. This important activity was not costed in any of the areas/activities of genebank operations.

Table 5.1. Operational Costs (US$) of ICRISAT Genebank: SORGHUM – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acce.)	Average quasi-fixed cost (US$/acce.)	Average variable labor cost (US$/acce.)	Average non-labor costs (US$/acce.)	Total AC*
Acquisition	21	14.86	1,543.62	0.00	146.12	**0.71**	**73.51**	**0.00**	**6.96**	**80.46**
Characterization	2,377	2,335.98	18,151.29	2,893.18	20,647.20	**0.98**	**7.64**	**1.22**	**8.69**	**17.54**
Safety duplication	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Long term storage	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Medium term storage	1,080	4,328.83	1,741.45	0.00	4,643.97	**4.01**	**1.61**	**0.00**	**4.30**	**5.91**
Germination testing	1,962	1,950.36	4,320.66	0.00	999.94	**0.99**	**2.20**	**0.00**	**0.51**	**2.71**
Regeneration	4,603	3,592.04	18,641.39	1,705.55	7,755.91	**0.78**	**4.05**	**0.37**	**1.68**	**6.11**
Seed processing	3,457	2,341.05	2,526.64	951.00	2,699.76	**0.68**	**0.73**	**0.28**	**0.78**	**1.79**
Seed health testing	300	0.00	777.38	0.00	1,200.64	**0.00**	**2.59**	**0.00**	**4.00**	**6.59**
Distribution	521	154.27	6,247.27	0.00	2,601.54	**0.30**	**11.99**	**0.00**	**4.99**	**16.98**
Information management	37,904	1,876.56	10,046.32	0.00	764.64	**0.05**	**0.27**	**0.00**	**0.02**	**0.29**
General management	37,904	7,371.98	42,078.18	0.00	1,743.12	**0.19**	**1.11**	**0.00**	**0.05**	**1.16**
Total**	**N.A.**	**23,965.95**	**106,074.19**	**5,549.73**	**43,202.84**	**8.69**	**105.69**	**1.86**	**31.98**	**139.54**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 5.2. Operational Costs (US$) of ICRISAT Genebank: PEARL MILLET – 2007

Activities	No. access.	Total capital cost **(US$)**	Total quasi-fixed cost **(US$)**	Total labor variable costs **(US$)**	Total non-labor costs **(US$)**	Average capital cost **(US$/acce.)**	Average quasi-fixed cost **(US$/acce.)**	Average variable labor cost **(US$/acce.)**	Average non-labor costs **(US$/acce.)**	Total AC*
Acquisition	423	299.32	9,901.07	0.00	2,943.20	**0.71**	**23.41**	**0.00**	**6.96**	**30.36**
Characterization	2,094	2,057.87	29,277.81	1,040.29	7,443.38	**0.98**	**13.98**	**0.50**	**3.55**	**18.03**
Safety duplication	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Long term storage	684	1,811.41	2,004.24	0.00	5,496.30	**2.65**	**2.93**	**0.00**	**8.04**	**10.97**
Medium term storage	112	448.92	180.60	0.00	481.60	**4.01**	**1.61**	**0.00**	**4.30**	**5.91**
Germination testing	2,433	2,418.57	5,105.32	0.00	1,239.99	**0.99**	**2.10**	**0.00**	**0.51**	**2.61**
Regeneration	793	618.83	26,246.09	8,148.23	12,914.52	**0.78**	**33.10**	**10.28**	**16.29**	**59.66**
Seed processing	1,723	1,166.80	1,909.19	897.42	1,394.39	**0.68**	**1.11**	**0.52**	**0.81**	**2.44**
Seed health testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Distribution	34	10.07	663.98	0.00	169.77	**0.30**	**19.53**	**0.00**	**4.99**	**24.52**
Information management	21,594	1,069.08	5,576.75	0.00	435.62	**0.05**	**0.26**	**0.00**	**0.02**	**0.28**
General management	21,594	4,199.84	24,424.74	0.00	993.06	**0.19**	**1.13**	**0.00**	**0.05**	**1.18**
Total**	**N.A.**	**14,100.70**	**105,289.77**	**10,085.95**	**33,511.83**	**11.34**	**99.15**	**11.29**	**45.51**	**155.96**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 5.3. Operational Costs (US$) of ICRISAT Genebank: CHICKPEA – 2007

Activities	No. access.	Total capital cost **(US$)**	Total quasi-fixed cost **(US$)**	Total labor variable costs **(US$)**	Total non-labor costs **(US$)**	Average capital cost **(US$/acce.)**	Average quasi-fixed cost **(US$/acce.)**	Average variable labor cost **(US$/acce.)**	Average non-labor costs **(US$/acce.)**	Total AC*
Acquisition	72	50.95	2,737.36	0.00	500.97	**0.71**	**38.02**	**0.00**	**6.96**	**44.98**
Characterization	1,200	1,179.29	20,166.96	5,107.71	21,462.73	**0.98**	**16.81**	**4.26**	**17.89**	**38.95**
Safety duplication	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Long term storage	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Medium term storage	2,581	10,345.11	4,161.75	0.00	11,098.24	**4.01**	**1.61**	**0.00**	**4.30**	**5.91**
Germination testing	2,871	2,853.97	5,835.00	0.00	1,463.21	**0.99**	**2.03**	**0.00**	**0.51**	**2.54**
Regeneration	1,650	1,287.61	21,447.29	4,179.04	17,735.80	**0.78**	**13.00**	**2.53**	**10.75**	**26.28**
Seed processing	4,231	2,865.20	3,742.22	2,678.87	3,899.52	**0.68**	**0.88**	**0.63**	**0.92**	**2.44**
Seed health testing	309	0.00	800.70	0.00	1,968.65	**0.00**	**2.59**	**0.00**	**6.37**	**8.96**
Distribution	944	279.51	10,790.19	0.00	4,713.73	**0.30**	**11.43**	**0.00**	**4.99**	**16.42**
Information management	20,140	997.10	6,324.16	0.00	406.29	**0.05**	**0.31**	**0.00**	**0.02**	**0.33**
General management	20,140	3,917.05	22,850.98	0.00	926.19	**0.19**	**1.13**	**0.00**	**0.05**	**1.18**
Total**	**N.A.**	**23,775.79**	**98,856.62**	**11,965.62**	**64,175.33**	**8.69**	**87.82**	**7.42**	**52.75**	**148.00**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 5.4. Operational Costs (US$) of ICRISAT Genebank: PIGEONPEA, 2006 - 2007

Activities	No. access.	Total capital cost **(US$)**	Total quasi-fixed cost **(US$)**	Total labor variable costs **(US$)**	Total non-labor costs **(US$)**	Average capital cost **(US$/acce.)**	Average quasi-fixed cost **(US$/acce.)**	Average variable labor cost **(US$/acce.)**	Average non-labor costs **(US$/acce.)**	Total AC*
Acquisition	0	0.00	1,052.07	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	798	784.23	19,190.65	7,179.37	7,372.68	**0.98**	**24.05**	**9.00**	**9.24**	**42.28**
Safety duplication	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Long term storage (2006)	247	956.98	1,303.45	0.00	2,868.13	**3.87**	**5.28**	**0.00**	**11.61**	**16.89**
Medium term storage	469	1,879.84	756.24	0.00	2,016.69	**4.01**	**1.61**	**0.00**	**4.30**	**5.91**
Germination testing (2006)	623	474.93	2,031.87	0.00	243.59	**0.76**	**3.26**	**0.00**	**0.39**	**3.65**
Regeneration	426	332.44	17,832.24	0.00	7,777.87	**0.78**	**41.86**	**0.00**	**18.26**	**60.12**
Seed processing	895	606.09	654.13	1,116.20	784.54	**0.68**	**0.73**	**1.25**	**0.88**	**2.85**
Seed health testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Distribution	270	79.95	3,744.40	0.00	1,348.21	**0.30**	**13.87**	**0.00**	**4.99**	**18.86**
Information management	13,632	674.90	4,960.51	0.00	275.00	**0.05**	**0.36**	**0.00**	**0.02**	**0.38**
General management	13,632	2,651.30	15,806.92	0.00	626.91	**0.19**	**1.16**	**0.00**	**0.05**	**1.21**
Total	**N.A.**	**7,008.73**	**65,049.26**	**8,295.57**	**20,201.89**	**6.99**	**83.64**	**10.24**	**37.73**	**131.62**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 5.5. Operational Costs (US$) of ICRISAT Genebank: GROUNDNUT – 2007

Activities	No. access.	Total capital cost **(US$)**	Total quasi-fixed cost **(US$)**	Total labor variable costs **(US$)**	Total non-labor costs **(US$)**	Average capital cost **(US$/acce.)**	Average quasi-fixed cost **(US$/acce.)**	Average variable labor cost **(US$/acce.)**	Average non-labor costs **(US$/acce.)**	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	900	718.50	31,252.19	6,409.20	14,709.24	**0.80**	**34.72**	**7.12**	**16.34**	**58.19**
Safety duplication	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Long term storage	1,931	4,154.17	5,658.16	0.00	15,516.61	**2.15**	**2.93**	**0.00**	**8.04**	**10.97**
Medium term storage	363	1,181.94	585.32	0.00	1,560.89	**3.26**	**1.61**	**0.00**	**4.30**	**5.91**
Germination testing	1,934	1,561.76	4,274.01	0.00	985.67	**0.81**	**2.21**	**0.00**	**0.51**	**2.72**
Regeneration	2,400	1,521.44	33,306.74	6,360.08	13,308.68	**0.63**	**13.88**	**2.65**	**5.55**	**22.07**
Seed processing	4,694	2,582.24	4,080.62	5,804.22	6,142.26	**0.55**	**0.87**	**1.24**	**1.31**	**3.41**
Seed health testing	1,475	0.00	3,822.11	0.00	5,965.14	**0.00**	**2.59**	**0.00**	**4.04**	**6.64**
Distribution	117	28.14	1,491.62	0.00	584.22	**0.24**	**12.75**	**0.00**	**4.99**	**17.74**
Information management	15,419	620.12	4,282.88	0.00	311.05	**0.04**	**0.28**	**0.00**	**0.02**	**0.30**
General management	15,419	2,436.11	17,741.12	0.00	709.09	**0.16**	**1.15**	**0.00**	**0.05**	**1.20**
Total**	**N.A.**	**14,804.42**	**106,494.75**	**18,573.50**	**59,792.84**	**8.64**	**72.99**	**11.01**	**45.15**	**129.15**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 5.6. Operational Costs (US$) of ICRISAT Genebank: SMALL MILLETS – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acce.)	Average quasi-fixed cost (US$/acce.)	Average variable labor cost (US$/acce.)	Average non-labor costs (US$/acce.)	Total AC*
Acquisition	43	30.43	2,058.57	0.00	299.19	**0.71**	**47.87**	**0.00**	**6.96**	**54.83**
Characterization	1,737	1,707.03	16,596.98	491.13	3,763.05	**0.98**	**9.55**	**0.28**	**2.17**	**12.00**
Safety duplication	3,042	2,031.15	21,508.12	0.00	3,930.45	**0.67**	**7.07**	**0.00**	**1.29**	**8.36**
Long term storage	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Medium term storage	147	589.20	237.03	0.00	632.10	**4.01**	**1.61**	**0.00**	**4.30**	**5.91**
Germination testing	127	126.25	1,263.65	0.00	64.73	**0.99**	**9.95**	**0.00**	**0.51**	**10.46**
Regeneration	1,737	1,355.50	14,741.86	8,929.57	3,537.64	**0.78**	**8.49**	**5.14**	**2.04**	**15.66**
Seed processing	4,926	3,335.85	3,600.30	4,987.16	3,953.89	**0.68**	**0.73**	**1.01**	**0.80**	**2.55**
Seed health testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Distribution	337	99.78	4,412.50	0.00	1,682.76	**0.30**	**13.09**	**0.00**	**4.99**	**18.09**
Information management	10,193	504.64	4,239.93	0.00	205.62	**0.05**	**0.42**	**0.00**	**0.02**	**0.44**
General management	10,193	1,982.45	12,084.66	0.00	468.75	**0.19**	**1.19**	**0.00**	**0.05**	**1.23**
Total**	**N.A.**	**11,762.28**	**80,743.59**	**14,407.86**	**18,538.18**	**9.36**	**99.97**	**6.44**	**23.12**	**129.54**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

SECTION 6

Conservation and Management of Genetic Resources of Major Food Crops of Africa in the IITA Genebank

D. Horna, V. M. Manyong, D. Dumet, A. Ogundapo

Recognizing the need to conserve this valuable germplasm for future use, the IITA genebank started operations in 1975. The bank presently holds over 28 000 accessions of major food crops of Africa, namely cowpea, cassava, yam, soybean, bambara groundnut, maize, plantain and banana (see Table 6.1 for details). In addition, substantial *Vigna* wild relatives and miscellaneous legumes have been collected over the past 40 years. More recently a small collection of African yam bean, an underutilized legume, has been added to the IITA genebank collection[21].

IITA Genetic Resources Center is maintaining germplasm in 3 different genebanks: Seed-, field- and in vitro-genebanks. Seed processing as well as yam and cassava in vitro banking operations are described in Dumet *et al*. 2007 (a, b), Dumet and Oyatomi 2008, Dumet and Ogunsola 2008, and Dumet *et al.* 2008[22]. The main challenge of IITA Genetic Resources Center is linked to the diversity of the collections in terms of genus, species, reproductive biology, agronomical multiplication and associated pathogens. As regard to the latter point, the existence of seed-born virus in the vigna germplasm as well as the accumulation of virus in yam, cassava and musa germplasm, make their sanitation very demanding in term of time and resources. Most likely the manipulation of this large crop diversity has implications on the total and average costs of conservation and distribution of materials. Another challenge for this genebank is the risk related to the location. Under this category we have 2 considerations: 1) the possibility of finding qualified temporary labor to perform high quality routine activities that required some level of specialization (i.e. cleaning, packing, selection of materials); 2) the possibility of having supplies and equipment delivered or fixed when they are needed. A common strategy to deal with the last point is to overstocked in supplied and have backup equipment to be prepared for

---

[21] http://www.iita.org/cms/details/genebank.aspx?articleid=1486&zoneid=358
[22] These manuals are available on line at www.iita.org.

eventualities. The consequence is however increase in total cost of operations, and the probability of having unused equipment that may deteriorate with time.

To our knowledge, this is the first costs evaluation carried out for the IITA genebank and thus the first attempt to evaluate the costs of managing and conserving African crops under *ex-situ* conditions.

Table 6.1: Types of materials and number of accessions hold by the IITA genebank

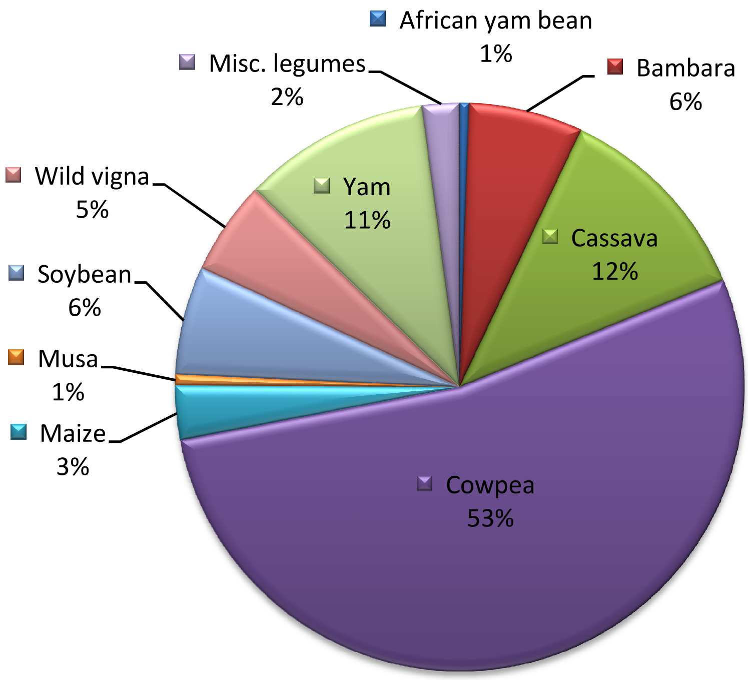
Common name		Latin Name	Accessions maintained	
			Total No.	No. In trust
Seed crops				
Cowpea	Niébé	*Vigna unguiculata* L.	15,115	15,003
Maize	Maïs	*Zea mays* L.	880	0
Soybean	Soja	*Glycine max (L.) Merr*	1,742	1,742
Bambara ground nut	Pois Bambara	*Vigna subterranean* (L.) Verdc	1,815	1,815
Wild Vigna		*Vigna*	1,507	1507
African yam bean	Haricot Igname	*Sphenostylis stenocarpa* (Hochst. ex A. Rich.) Harms	66	66
Miscellaneous legumes	Winged bean	*Psophocarpus tetragonolobus*	> 600	0
	Pigeon pea	*Cajanus cajun*		
	Lablab	*Lablab purpureus*		
	Lima bean	*Phaseolus lunatus*		
	Jack- and sword-bean	*Canavalia species*		
	Green gram	*Vigna radiata*		
	Mung bean	*Vigna mungo*		
Clonal crops				
Cassava	Manioc	*Manihot esculenta* Crantz	2,712	2,078
Yam	Igname	*Dioscorea abysinnica,*	3,200	3,087
		D. alata		
		D. bulbifera		
		D. cayenensis		
		D. dumentorum		
		D. esculenta		
		D. manganotiana		
		D. Preusii		
		D. rotundata		
Banana/Plantain	Banane	*Musa acuminata*	250	0
		M. balbisiana		
		M. schizocarpa		
		M. basjoo		
		M. laterita		
		M. peekeli		

Source: IITA 2009 (http://www.iita.org/cms/details/genebank.aspx?articleid=1486&zoneid=358)

6.1. Data

IITA staff collected accessions processed, input use, and related cost data for the year 2008 using the DST. This is a very good example of how the tool can be implemented by each genebank in the CG center. However, the tool was adapted to specifics of the genebank at IITA. The information collected allowed the estimation of actual total and averages costs of the all operations performed in the genebank. Since this genebank holds a diversity of crops the title of operations were adjusted to report both the costs of seed and clonal materials (Figure 7.1). Note that this information might suffer from a downward bias on the total non-labor variable costs since it is difficult to account for every type of supply used in the genebank. Also, we only count with one year of information, 2008, and this could be considered a baseline year for future estimations. Note in this particular year the IITA genebank was very active in the upgrading the bank – i.e. more samples treated per operation than an annual year, large quantity of supplies bought, and many people involved in several operations. Periodical collection of genebank costs would allow formulating more solid conclusions about the costs-effectiveness of the IITA genebank collection.

Figure 6.1. Types of accessions held at the IITA genebank



6.2. Results

Costs reports per operation and type of material for the IITA genebank are presented in Table 6.2 to 6.11.

The African yam bean is grown in West Africa, particularly in Cameroon, Cote d'Ivoire, Ghana, Nigeria and Togo (Porter 1992). It is in danger of extinction because of the competition with other major legumes and because it receives no research attention locally (Klu *et al.* 2001). African yam bean is a vigorous vine with edible seeds and underground tubers used as food in some parts of Africa (Duke *et al.* 1977; Anon 1979; Porter 1992). In general it looks that this collection demands relatively low investment of IITA resources compare to other types of materials managed at this genebank. In 2008 the cost of distribution recorded the highest costs (Table 6.2). This distribution costs refers exclusively to inputs and resources used for packing and shipping of materials to users. On this year a total of 75 accessions were distributed accounting for US$ 1,278 in total or US$ 19.67 per accession (these values do not include the investment in capital costs). Regeneration accessions of African yam beans also require some investment. In average the regeneration of each accession was about US$ 14.90 (not including capital costs). Not all the genebank operations were carried out in 2008, i.e. there were no new accession acquired, tested for viability or seed health.

Bambara groundnut originated in West Africa, probably north-eastern Nigeria and northern Cameroon. It is found in many farming systems of many countries in west, central, southern, and east Africa. This little-known vegetable has potential to improve nutrition, boost food security, foster rural development and support sustainable land management (National Research Council 2006). It contributes greatly to diversity. The IITA genebank holds the largest germplasm collection of Bambara groundnut. In 2008 the genebank was very active on the Bambara groundnut collection. A comparatively large number of materials that were regenerated (402), sent for safety duplication (269), characterized (124) and tested for viability (494) and health (153). Distribution (US$ 19.67 /accession), seed health testing (US$ 12.71/ accession) and regeneration (US$ 10.49/accession) reported the highest average costs. In terms of total cost the distribution of Bambara groundnut was the operation that recorded the highest costs (US$ 9.088). In

2008, 461 accessions were distributed to 9 distinct recipients from 3 different countries: Nigeria, UK and Denmark. Shipping cost include DHL shipment for the last 2 countries.

Cassava was introduced from South America in the sixteen century, and quickly spread through the African continent. Cassava has become the ideal crop in many farming systems in Africa because of its adaptability of the crops to marginal soils and erratic rainfall conditions, and high-yield per unit of land (Nweke *et al.* 2002). Nowadays cassava is the second most important food in the African diet. Despite that the largest diversity of this clonal crop comes mainly from the center of origin (South America), the African cultivars has evolved into distinctive materials that need to be conserved. Indeed, amongst the African landraces, some of them have developed resistance towards cassava viruses found on the African continent. Such landraces are very valuable for future genetic improvement of the crop.

As a clonal crop, the conservation of this material tends to be more expensive than seed crops. Presently, IITA genebank maintains and multiplies its cassava collection as plants in a field genebank) or as seedlings in the in-vitro genebank. Cryopreservation is at a development stage which may explain the high average cost (US$ 53.23) per accession processed in 2008. This can also be due to the low number of accession maintained under these conditions (50 accessions). The most expensive operation however was the acquisition of new materials (US$ 164.42/accession). The acquisition involved a two weeks collecting mission in Guinea Conackry. It should be noted however such a high cost for acquisition is not repeated every year. Seed health testing (US$ 12.71/accession) and distribution (US$ 19.67/ accession) also recorded high average costs. In terms of total costs however it was characterization that demanded the highest investment (above US$ 29,177). The average cost of cassava characterization however was only US$ 6.48 per accession. Note that a large number of accessions (4,500) were characterized in 2008. Also note that characterization was performed into 2 different locations involving extra cost associated to per diem and accommodation of genebank staff.

Cowpea grain (*Vigna unguiculata* subsp. *unguiculata* (L.) Walp.) is a major source of protein in Sub-Saharan African where the bulk of it is produced and consumed. This is a cheap source of plant protein and the most important pulse crop in the savanna regions of

West and Central Africa, while in East and southern Africa serves as both, vegetable and pulse. Cowpea also plays an important role in multiple cropping systems and is a major source of fodder for livestock of integrated crop/livestock systems in West Africa (Madamba *et al.* 2006). There are two centers of diversity for cowpea: Tropical Africa and India/Southeast Asia. The collection, conservation and usage of cowpea germplasm in IITA commenced right from the onset of the institute in July 1967. The collection was tremendously expanded after the establishment of IITA's Genetic Resources Unit (GRU) in 1975. The unit collaborated with many national programs and International Plant Genetic Resources Institute (IPGRI) to undertake 60 systematic plant exploration missions in 31 African countries on wild relatives of cowpea and other wild *Vigna* germplasm (Goldsworthy, 1982 and Ng, 1990). As at 2009, IITA maintains a collection of over 15,000 cowpea accessions of cultivated varieties from over 100 countries and 1632 accessions of wild cowpeas (*vigna*). In total costs terms, the genebank invested most of their resources (US$ 29,624) on the regeneration of 2,228 accessions of cowpea in 2008, leading to an average costs of approximately US$ 13.30 per accession. Seed health testing (US$ 13.94/ accession) and distribution (US$ 19.67 /accession) were also operations that recorded high costs. In the case of cowpea, indexing and clean seed production is costly as it involved screen house regeneration, diagnostic of each single plant, elimination of infested one and harvesting from clean plants only. In 2008, there was no acquisition of new cowpea materials, neither characterization of new materials.

Maize was introduced from the Americas to Africa along the western and eastern coasts in the 16th century, gradually moving inward to the countries displacing major crops as millet and sorghum. As a predominantly a cross-pollinating maize, diversity has evolved in Africa into own materials, races and populations that need to be conserved. The IITA genebank holds a total of 878 accessions of maize which are mainly landraces collected exclusively from Africa. The highest conservation costs in 2008 were distribution (US$ 19.67 /accession) and regeneration (US$ 14.39 /accession). Note that other operations like characterization and safety duplication were comparatively affordable for a crop that requires special multiplication conditions. In 2008 the IITA genebank did not acquired any new maize accessions; neither seed health was evaluated for this crop.

Plantains and bananas are clonal crops and their conservation usually involves different techniques from field genebanks to in-vitro and cryopreservation practices. At the IITA genebank the most expensive technique is cryopreservation, US$ 26.55/accession compared to US$ 4.48/accession for in-vitro or US$ 3.32/ accession for field genebank conservation. These figures however represent annual average costs. The high cost of cryopreservation is due to the fact that cryopreservation is still in development phase. In other words, many meristems need to be processed per trials to control the effect of the different treatments on germplasm viability. Cryopreservation is a long term conservation method that in theory allows the materials to be conserved forever, as opposed to 0.4 years in vitro in IITA standard conditions in which subcultured is needed every 4 months. Seed health testing and distribution of *Musa spp.* accessions are also expensive operations. In 2008 the costs of screening plantains and bananas for the most common diseases was US$ 19.67/ accession. In 2008, there were only 4 accessions distributed, and no new accessions acquired, characterized or sent for safety duplication.

Soybean is a legume that grows in tropical, subtropical, and temperate climates. It is believed that it might have been introduced to Africa in the 19th century by Chinese traders along the east coast of Africa. Soybean is an important source of high quality but inexpensive protein and oil[23]. Since the 1970s IITA has been working on the production on advanced breeding lines and varieties that adapt better to African conditions. The IITA genebank holds around 1,700 accessions of soybean, which in as much to the other collections were collected mainly out of Africa. In 2008 the most important operation performed on soybean accession was safety duplication and distribution, in addition to store the materials in long term and medium term conditions. A total of 673 accessions were duplicated with a cost of US$ 3.95 / accession, and 9 accessions were distributed in three countries (Nigeria, Switzerland and Malawi) with an average cost of US$ 19.67.

The IITA genebank also holds accession of wild vigna (1,516) and some miscellaneous legumes (about 600 accessions).The maintenance of cowpea wild relative is important as this collection may become an interesting source of gene for future genetic improvement. The costs of conserving and maintaining these materials are reported in Table 6.9. In 2008

[23] http://www.iita.org/cms/details/soybean_project_details.aspx?zoneid=63&articleid=270

the main operations performed on wild vigna were the distribution of 184 accessions at a cost of US$ 19.67 /accession and the characterization of 737 accessions at a cost of US$ 5.00/ accession.

Yam is an annual or perennial tuber-bearing and climbing plant. In addition to their food and market values, yam plays a major role in the life of smallholder households, especially in West Africa. According to FAO statistics[25], in 2005 sub-Saharan Africa accounted for 97% of worldwide production while West and Central Africa account for about 94% of that total. Yam belongs to the genus *Dioscorea* that has over 600 species. In Africa White Guinea yam (*D. rotundata Poir*) is the most important food species in terms of cultivation and utilization[24]. Large part of yam diversity remains on farmers fields. IITA genebank maintains over 3,200 accessions of yam under in-vitro and field conditions. In 2008, the operation that demanded more resources in the conservation and management of yam germplasm was regeneration (US$ 38,495, US$ 12.03/accession). This high cost is to be linked to the low efficiency of the existing in vitro introduction process i.e. one accession needs several processing prior transfer into the in vitro genebank (Table 6.10). If we add this total added to the maintenance of the field genebank we can have an idea of the complexity of maintaining this type of clonal material. In 2008, there were no cryopreservation tests on yam, neither new materials acquired or characterized. The costs of seed health testing (US$ 12.71) and distribution (US$ 21.27) were as in the case of other clonal and seed materials considerably higher than other operations. In the case of yam, sanitation is very demanding. Indeed, it requires the in vitro introduction of each accession in vitro, their acclimatization in vivo and their re-introduction in vitro once the plants are certified clean from virus.

Table 6.1 lists the miscellaneous legumes conserved in the genebank and Table 6.11 presents the costs reports for these materials. This collection is presently under evaluation. It contains various under used crops that may become interesting in a close future. However, as non IITA mandate crop only regeneration and distribution is performed on this germplasm. The diversity of crops probably adds to the complexity of operations and increases the costs. This could be the case of seed processing that includes drying,

[24] http://www.iita.org/cms/details/yam_project_details.aspx?zoneid=63&articleid=268

cleaning and packing. In 2008 the costs of seed processing of these miscellaneous legumes reached US$ 7.82/accession. Seed health testing (US$ 12.71) and distribution (US$ 19.67) of miscellaneous accessions ranked also high in terms of total and average costs.

Table 6.2. Operational Costs of IITA Genebank: AFRICAN YAM BEAN– 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	4	7.70	14.11	1.72	4.19	**1.93**	**3.53**	**0.43**	**1.05**	**5.00**
Safety duplication	4	6.20	7.43	2.17	6.20	**1.55**	**1.86**	**0.54**	**1.55**	**3.95**
Seed long term storage	152	350.36	65.92	43.97	40.12	**2.31**	**0.43**	**0.29**	**0.26**	**0.99**
Seed medium term storage	152	467.48	116.11	41.06	35.07	**3.08**	**0.76**	**0.27**	**0.23**	**1.26**
Germination testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Regeneration	61	184.14	242.12	569.95	97.13	**3.02**	**3.97**	**9.34**	**1.59**	**14.90**
Seed processing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed health testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Distribution	65	186.05	533.82	59.61	685.24	**2.86**	**8.21**	**0.92**	**10.54**	**19.67**
Information management	152	98.25	153.68	48.97	17.40	**0.65**	**1.01**	**0.32**	**0.11**	**1.45**
General management	152	43.95	155.67	39.25	28.95	**0.29**	**1.02**	**0.26**	**0.19**	**1.47**
Total**	**N.A.**	**1,344**	**1,289**	**807**	**914**	**15.67**	**20.80**	**12.37**	**15.53**	**48.70**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 6.3. Operational Costs of IITA Genebank: BAMBARA NUT– 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	124	238.83	437.51	53.22	190.81	**1.93**	**3.53**	**0.43**	**1.54**	**5.50**
Safety duplication	269	416.82	500.00	145.67	477.86	**1.55**	**1.86**	**0.54**	**1.78**	**4.18**
Seed long term storage	1,843	4,248.13	799.34	533.17	486.48	**2.31**	**0.43**	**0.29**	**0.26**	**0.99**
Seed medium term storage	1,843	5,668.17	1,407.89	497.84	425.19	**3.08**	**0.76**	**0.27**	**0.23**	**1.26**
Germination testing	494	953.26	1,497.32	1,101.03	385.02	**1.93**	**3.03**	**2.23**	**0.78**	**6.04**
Regeneration	402	1,213.53	1,595.58	1,511.00	1,110.51	**3.02**	**3.97**	**3.76**	**2.76**	**10.49**
Seed processing	596	17,857.91	2,636.21	1,366.82	656.93	**29.96**	**4.42**	**2.29**	**1.10**	**7.82**
Seed health testing	153	1,843.88	540.81	156.22	1,248.03	**12.05**	**3.53**	**1.02**	**8.16**	**12.71**
Distribution	462	1,322.40	3,794.19	423.66	4,870.44	**2.86**	**8.21**	**0.92**	**10.54**	**19.67**
Information management	1,843	1,191.32	1,863.37	593.74	213.38	**0.65**	**1.01**	**0.32**	**0.12**	**1.45**
General management	1,843	532.94	1,887.49	475.96	351.05	**0.29**	**1.02**	**0.26**	**0.19**	**1.47**
Total**	**N.A.**	**35,487**	**16,960**	**6,858**	**10,416**	**59.62**	**31.79**	**12.33**	**27.46**	**71.58**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 6.4. Operational Costs of IITA Genebank: CASSAVA– 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acce.)	Total AC*
Acquisition	30	867.07	1,558.94	291.38	3,082.21	**28.90**	**51.96**	**9.71**	**102.74**	**164.42**
Characterization	4,500	8,667.12	15,877.22	5,641.33	7,659.18	**1.93**	**3.53**	**1.25**	**1.70**	**6.48**
Safety duplication	624	966.90	1,159.85	2,388.29	3,316.44	**1.55**	**1.86**	**3.83**	**5.31**	**11.00**
Seed medium term storage	100	307.55	76.39	27.01	23.07	**3.08**	**0.76**	**0.27**	**0.23**	**1.26**
Seed health testing	316	3,808.27	1,116.98	322.66	2,577.63	**12.05**	**3.53**	**1.02**	**8.16**	**12.71**
Distribution	34	97.32	279.23	31.18	358.43	**2.86**	**8.21**	**0.92**	**10.54**	**19.67**
Information management	3,368	2,177.09	3,405.23	2,401.32	408.77	**0.65**	**1.01**	**0.71**	**0.12**	**1.85**
General management	3,368	973.92	3,449.31	869.79	644.75	**0.29**	**1.02**	**0.26**	**0.19**	**1.47**
Clonal long term storage	50	1,720.78	1,436.60	104.38	1,120.54	**34.42**	**28.73**	**2.09**	**22.41**	**53.23**
Clonal med. term storage in vitro	2455	9,573.07	6,649.60	427.38	3,925.22	**3.90**	**2.71**	**0.17**	**1.60**	**4.48**
Clonal med. term field bank	3388	2,973.24	5,516.68	5,076.59	776.21	**0.88**	**1.63**	**1.50**	**0.23**	**3.36**
Total**	**N.A.**	**32,132**	**40,526**	**17,581**	**23,892**	**90.50**	**104.97**	**21.73**	**153.24**	**279.94**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 6.5. Operational Costs of IITA Genebank: COWPEA– 2008

Activities	No. acces s.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc.)	Average quasi-fixed cost (US$/acc.)	Average variable labor cost (US$/acc.)	Average non-labor costs (US$/acc.)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	4,778	7,403.62	8,881.01	2,587.36	7,539.04	**1.55**	**1.86**	**0.54**	**1.58**	**3.98**
Seed long term storage	15,113	34,835.55	6,554.73	4,372.14	3,989.23	**2.31**	**0.43**	**0.29**	**0.26**	**0.99**
Seed medium term storage	15,113	46,480.26	11,544.96	4,082.42	3,486.66	**3.08**	**0.76**	**0.27**	**0.23**	**1.26**
Germination testing	2,360	4,554.03	7,153.20	5,259.96	1,839.39	**1.93**	**3.03**	**2.23**	**0.78**	**6.04**
Regeneration	2,228	6,725.75	8,843.16	16,494.90	3,198.97	**3.02**	**3.97**	**7.40**	**1.44**	**12.81**
Seed processing	1,346	40,330.12	5,953.59	3,086.80	1,569.03	**29.96**	**4.42**	**2.29**	**1.17**	**7.88**
Seed health testing	1,451	17,486.70	5,128.90	3,268.90	11,835.87	**12.05**	**3.53**	**2.25**	**8.16**	**13.94**
Distribution	475	1,359.61	3,900.96	435.58	6,410.68	**2.86**	**8.21**	**0.92**	**13.50**	**22.63**
Information management	15,113	9,769.11	15,280.05	6,628.05	1,734.92	**0.65**	**1.01**	**0.44**	**0.11**	**1.56**
General management	15,113	4,370.19	15,477.86	6,411.62	2,878.68	**0.29**	**1.02**	**0.42**	**0.19**	**1.64**
Total**	**N.A.**	**173,315**	**88,718**	**52,628**	**44,482**	**57.69**	**28.26**	**17.06**	**27.41**	**72.73**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 6.6. Operational Costs of IITA Genebank: MAIZE– 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	100	192.60	352.83	42.92	283.97	**1.93**	**3.53**	**0.43**	**2.84**	**6.80**
Safety duplication	499	773.21	927.51	270.22	952.61	**1.55**	**1.86**	**0.54**	**1.91**	**4.31**
Seed long term storage	878	2,023.80	380.80	254.00	231.76	**2.31**	**0.43**	**0.29**	**0.26**	**0.99**
Seed medium term storage	878	2,700.30	670.71	237.17	202.56	**3.08**	**0.76**	**0.27**	**0.23**	**1.26**
Germination testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Regeneration	132	398.47	523.92	321.34	1,054.42	**3.02**	**3.97**	**2.43**	**7.99**	**14.39**
Seed processing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed health testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Distribution	47	134.53	385.99	43.10	495.48	**2.86**	**8.21**	**0.92**	**10.54**	**19.67**
Information management	878	567.54	887.70	282.86	102.90	**0.65**	**1.01**	**0.32**	**0.12**	**1.45**
General management	878	253.89	899.20	226.75	167.24	**0.29**	**1.02**	**0.26**	**0.19**	**1.47**
Total**	**N.A.**	**7,044**	**5,029**	**1,678**	**3,491**	**15.67**	**20.80**	**5.46**	**24.08**	**50.34**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 6.7. Operational Costs of IITA Genebank: MUSA– 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	0	0.00	0.00	0.00	36.01	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed health testing	83	1,000.27	293.38	84.75	677.03	**12.05**	**3.53**	**1.02**	**8.16**	**12.71**
Distribution	4	11.45	32.85	3.67	42.17	**2.86**	**8.21**	**0.92**	**10.54**	**19.67**
Information management	173	94.92	174.91	55.73	20.86	**0.55**	**1.01**	**0.32**	**0.12**	**1.45**
General management	173	88.77	177.18	44.68	33.25	**0.51**	**1.02**	**0.26**	**0.19**	**1.47**
Clonal long term storage	36	91.49	73.79	75.16	806.79	**2.54**	**2.05**	**2.09**	**22.41**	**26.55**
Clonal med. term storage in vitro	230	896.87	622.98	40.04	367.74	**3.90**	**2.71**	**0.17**	**1.60**	**4.48**
Clonal med. term field bank	482	422.99	784.84	722.23	91.76	**0.88**	**1.63**	**1.50**	**0.19**	**3.32**
Total**	**N.A.**	**2,607**	**2,160**	**1,026**	**2,076**	**23.29**	**20.17**	**6.28**	**43.21**	**69.66**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 6.8. Operational Costs of IITA Genebank: SOYBEAN– 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	673	1,042.83	1,250.93	364.44	1,042.99	**1.55**	**1.86**	**0.54**	**1.55**	**3.95**
Seed long term storage	1,751	4,036.07	759.43	506.56	462.19	**2.31**	**0.43**	**0.29**	**0.26**	**0.99**
Seed medium term storage	1,751	5,385.23	1,337.61	472.99	403.97	**3.08**	**0.76**	**0.27**	**0.23**	**1.26**
Germination testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Regeneration	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed processing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed health testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Distribution	9	25.76	73.91	8.25	94.88	**2.86**	**8.21**	**0.92**	**10.54**	**19.67**
Information management	1,751	1,131.85	1,770.35	564.10	200.46	**0.65**	**1.01**	**0.32**	**0.11**	**1.45**
General management	1,751	506.33	1,793.27	452.20	333.53	**0.29**	**1.02**	**0.26**	**0.19**	**1.47**
Total**	**N.A.**	**12,128**	**6,986**	**2,369**	**2,538**	**10.73**	**13.30**	**2.60**	**12.89**	**28.79**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 6.9. Operational Costs of IITA Genebank: WILD VIGNA– 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	737	1,419.48	2,600.34	316.33	771.66	**1.93**	**3.53**	**0.43**	**1.05**	**5.00**
Safety duplication	294	455.56	546.47	159.21	455.63	**1.55**	**1.86**	**0.54**	**1.55**	**3.95**
Seed long term storage	1,516	3,494.39	657.51	438.57	400.16	**2.31**	**0.43**	**0.29**	**0.26**	**0.99**
Seed medium term storage	1,516	4,662.48	1,158.09	409.51	349.75	**3.08**	**0.76**	**0.27**	**0.23**	**1.26**
Germination testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Regeneration	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed processing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed health testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Distribution	184	526.67	1,511.11	168.73	1,939.74	**2.86**	**8.21**	**0.92**	**10.54**	**19.67**
Information management	1,516	979.95	1,532.76	488.40	173.55	**0.65**	**1.01**	**0.32**	**0.11**	**1.45**
General management	1,516	438.38	1,552.60	391.51	288.76	**0.29**	**1.02**	**0.26**	**0.19**	**1.47**
Total**	**N.A.**	**11,977**	**9,559**	**2,372**	**4,379**	**12.65**	**16.83**	**3.03**	**13.94**	**33.80**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 6.10. Operational Costs of IITA Genebank: YAM– 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	816	1,264.41	1,516.72	471.63	1,521.53	**1.55**	**1.86**	**0.58**	**1.86**	**4.30**
Regeneration	3,200	9,659.97	12,701.13	15,033.26	10,761.04	**3.02**	**3.97**	**4.70**	**3.36**	**12.03**
Seed processing	338	4,073.40	1,194.74	345.12	2,757.08	**12.05**	**3.53**	**1.02**	**8.16**	**12.71**
Seed health testing	642	1,837.61	5,272.45	1,611.82	6,768.02	**2.86**	**8.21**	**2.51**	**10.54**	**21.27**
Distribution	3,039	1,964.42	3,072.59	2,475.47	364.98	**0.65**	**1.01**	**0.81**	**0.12**	**1.95**
Information management	3,039	878.78	3,112.37	1,388.52	583.40	**0.29**	**1.02**	**0.46**	**0.19**	**1.67**
General management	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Clonal med. term storage in vitro	1,641	6,398.94	4,444.80	285.68	2,623.74	**3.90**	**2.71**	**0.17**	**1.60**	**4.48**
Clonal med. term field bank	3,200	2,808.26	5,210.56	4,794.89	627.03	**0.88**	**1.63**	**1.50**	**0.20**	**3.32**
Total**	**N.A.**	**28,886**	**36,525**	**26,406**	**26,007**	**25.19**	**23.95**	**11.75**	**26.03**	**61.73**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 6.11. Operational Costs of IITA Genebank: MISCELLANEOUS LEGUMES– 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed long term storage	2,000	4,610.01	867.43	578.59	527.92	**2.31**	**0.43**	**0.29**	**0.26**	**0.99**
Seed medium term storage	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Germination testing	322	621.35	975.99	717.67	250.97	**1.93**	**3.03**	**2.23**	**0.78**	**6.04**
Regeneration	165	498.09	654.90	186.39	262.73	**3.02**	**3.97**	**1.13**	**1.59**	**6.69**
Seed processing	319	9,558.18	1,410.99	731.57	351.54	**29.96**	**4.42**	**2.29**	**1.10**	**7.82**
Seed health testing	202	2,434.40	714.02	206.26	1,647.72	**12.05**	**3.53**	**1.02**	**8.16**	**12.71**
Distribution	122	349.20	1,001.93	111.88	1,286.13	**2.86**	**8.21**	**0.92**	**10.54**	**19.67**
Information management	600	387.84	606.63	193.30	68.69	**0.65**	**1.01**	**0.32**	**0.11**	**1.45**
General management	600	173.50	614.49	154.95	114.29	**0.29**	**1.02**	**0.26**	**0.19**	**1.47**
Total**	**N.A.**	**18,633**	**6,846**	**2,881**	**4,510**	**53.07**	**25.64**	**8.46**	**22.74**	**56.84**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

SECTION 7

Conservation and Management of Forage Genetic Resources in the ILRI Genebank

D. Horna, J. Hanson

The success of a forage research or development and improvement program usually depends on the availability of adapted, productive and appropriate forage germplasm for selection of promising lines. In most African countries, such germplasm was difficult to obtain (Hanson and Lazier 1989). Given this constraint, the International Livestock Research Institute (ILRI) established a forage genetic resources collection in 1982. Currently, ILRI conserves in trust about 19,000 accessions of forages that represent over 750 species (see Table 7.1). This is one of the most diverse collections of forage grasses, legumes and fodder tree species held in any genebank in the world and includes the world's major collection of African grasses and tropical highland forages[25]. ILRI maintains both an active and base collection in Addis Ababa. The active genebank is used for current research and distribution of seeds. All seeds in the active collection are freely available in small quantities to forage research workers. The materials are distributed both directly and through networks. The base genebank is used for long-term security storage of original germplasm collections.

Table 7.1. Types of materials and number of accessions held by the ILRI genebank

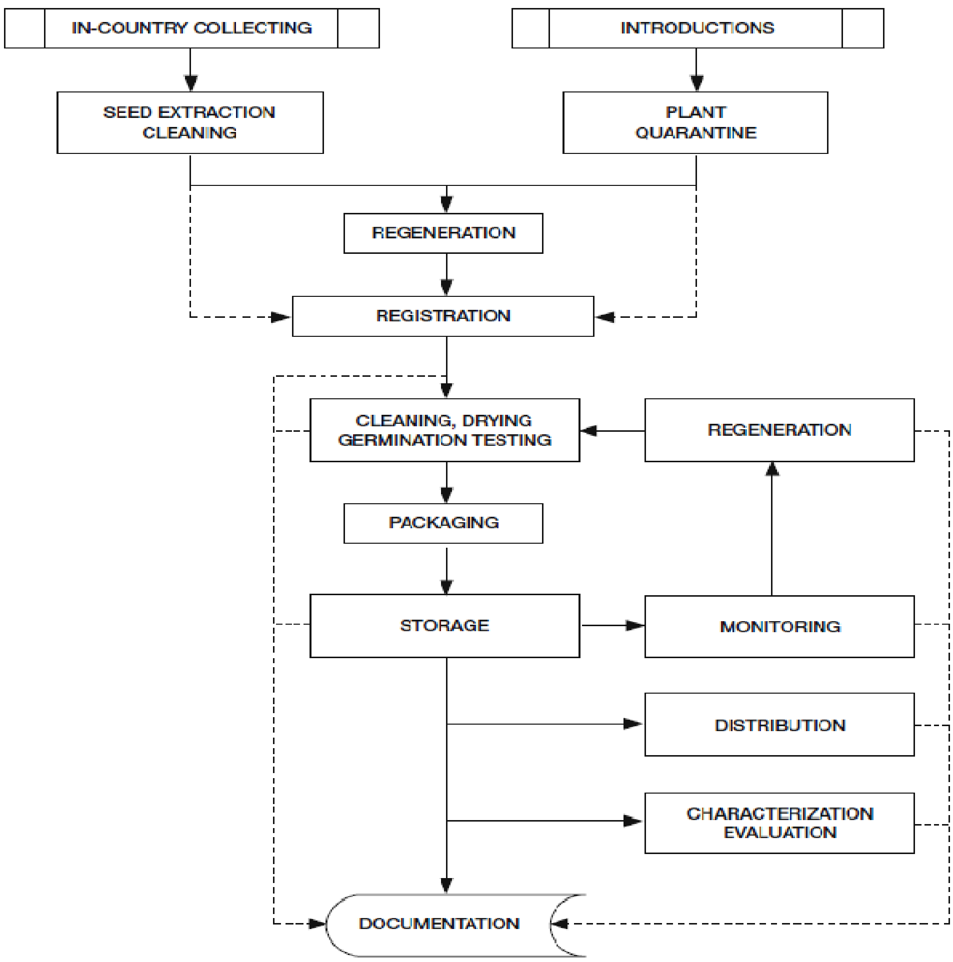
Common name	No. of genera	No. of species	Accessions maintained	
			Total No.	No. In trust
Seed crops				
Forage grasses	123	495	4361	4334
Forage legumes	83	611	10705	10629
Fodder trees	167	531	3526	3518
Other forages	53	111	254	246
Clonal crops				
Forages grasses	2	3	61	60
Total	**428**	**1751**	**18907**	**18787**

[25] http://www.ilri.org/ilrinews/index.php/archives/452

For performing the evaluation of the ILRI genebank cost effectiveness it was necessary to take into consideration that the majority of these materials are wild species that require special management and have little published information about their breeding systems, seed germination and storage behavior in genebanks. Regeneration and multiplication of these materials are particularly challenging as the different species have very different behavior in the field. Therefore while a small genebank in number of accessions the manipulation of a large diversity of materials requires considerable investment in equipment and human capital. Similar to the conditions for IITA, the location of the ILRI genebank while ideal for distribution in materials within Africa, it also involves some risks. For instance, the replacement of capital equipment and sourcing of spare parts for equipment maintenance could take a longer time than expected.

The materials held in the ILRI genebank are mainly seed propagated, and thus the genebank follows the flow of operations that a normal seed genebank does (see Figure 7.1). There are however a number of materials that produce seeds with short longevity or that do not produce seeds. These types of materials are kept on field genebanks. A factor affecting seed production is the identification of appropriate agro-ecological conditions for each type of material. A consequence of not having the most appropriate conditions for regeneration and multiplication has an impact on the total seed produced and thus on the total costs of conserving and distributing forages accessions. Ethiopia has a wide range of agroecologies and soil types and sites have been identified where most species will produce seeds.

Figure 7.1. Flow chart for germplasm management followed by the ILRI genebank



Source: Rao *et al.* 2006

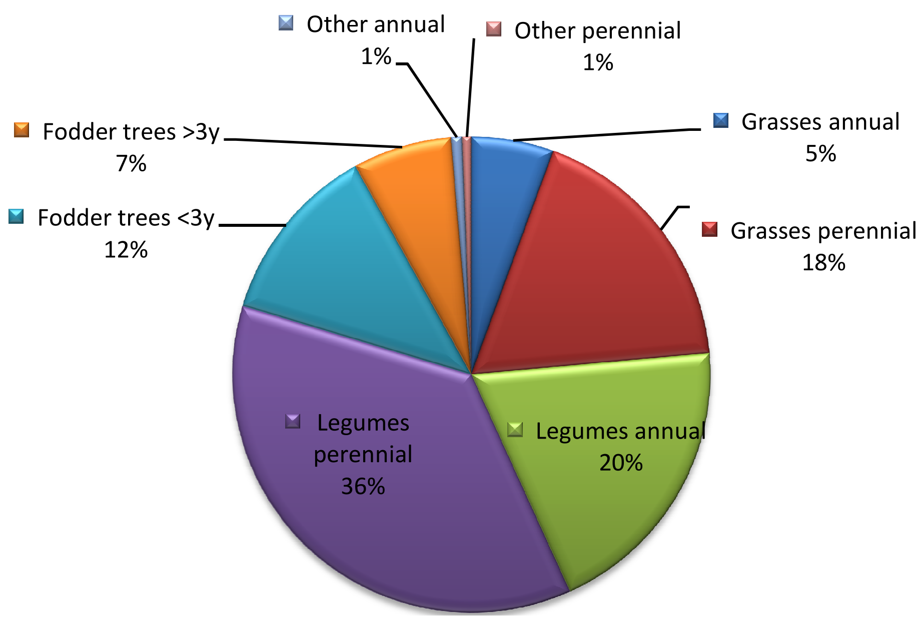
7.1. Data

The information collected for this evaluation corresponds to the years 2006 and 2007. The materials held in the genebank were classified in 6 main types: grasses annual (5%) and perennial (18%), legumes annual (20%) and perennial (36%)[26], fodder trees with a regeneration period of less than 3 years (12%) and forage trees with regeneration period of more than 3 years (7%). Materials that do not fit this classification were grouped as “other annual” (1%) and “other perennial” (1%) forages (see Figure 7.2). Similar to other genebanks, the non-labor variable data might suffer from a downward bias. It is rather

[26] CIAT has been the major contributor to the collection providing accessions from Central and South America (http://www.ilri.org/InfoServ/Webpub/Fulldocs/X5491e/x5491e0b.htm#germplasm%20data).

difficult to account for every input used in the conservation of this germplasm. Genebank staff and managers usually report the inputs most frequently used. Also, for the case of ILRI, the use on non-labor variable inputs is reported and an annual average. Therefore the difference across years in average costs is basically due to the number of accessions manipulated per operation. If the number of accessions was higher than the previous year, then, the average cost this year will be lower.

Figure 7.2. Forage accessions at the ILRI Genebank according to type of material



7.2. Results

Tables 7.2 to 7.9 present the information of total and average cost per operation and per type of material in the ILRI genebank in 2007. Evidently the largest investment in this genebank goes to the annual and perennial legumes given the large number of accessions. Also note that in 2007 ILRI genebank did not acquire new accessions.

Annual grasses are important components of the livestock production systems in poor and marginal areas of Africa, Asia and Latin America. They are important in drylands surviving the long dry seasons as seeds stocks in the soil and germinating and growing rapidly with the onset of the rains. There are few institutes dedicated to the conservation of this genetic diversity. ILRI holds a collection of 1,046 accessions that represent 82 species. The cost of conserving and distribution accession of annual grasses is relatively high given the great diversity of species manipulated. Table 7.2 present a summary of total and average costs of conservation of these materials in the ILRI genebank for the year 2007. Not surprisingly, regeneration of accessions records the highest average costs in 2007 (US$ 76/accession). Seed processing (US$/accession), seed health testing (US$ 24/accession) and distribution (US$ 15) are also expensive operations. In 2007 there was no acquisition of annual grasses, neither characterization nor evaluation of viability. In this year no new accessions were store either in the long term of medium term.

Perennial grasses are the major component of tropical rangelands throughout the world and support livestock production in many countries, including the cultivated grasses that have been developed as livestock feed. The majority of forage grasses in the collection in ILRI are perennial with many of them being conserved in the field genebank. The main conservation operations performed on these materials in 2007 were seed processing, viability testing, regeneration, seed health testing, storing into long and medium term conditions, and distribution. Among them the operation that reported the highest average costs was viability testing (US$ 86), but in total term it only added to about US$ 250. The problem with the estimation of averages is that fixed and quasi-fixed costs tend to increase average costs when the number of accessions manipulated is low. So, while the average cost of regeneration in 2007 was high, it only reflects that the genebank could increase its efficiency by increasing the number of accessions manipulated. Very often however the factors affecting the decision about number of accessions that need to be manipulated per operation are difficult to control. Also notice that in total costs the most expensive operation was medium term storage (US$ 19/accession). This is basically due to the fact that medium term storage of perennial grasses includes the field genebank costs.

Annual legumes are important in the tropical highlands and in areas with long dry seasons. Annual species fit well into cropping systems and as cover crops. Despite being second in number of accessions, annual legumes used most resources than the other types of materials kept at the ILRI genebank. In 2007 this added to a total US$ 128,200. The most expensive operations were regeneration (US$ 76/accession) and characterization (US$ 52 / accession). This is understandable given the diversity of materials and the special demand according to the needs of each material. Testing of seed health (US$ 31/accession) and viability (US$ 36/accession) also demanded high investments mainly on capital and quasi-fixed labor.

Perennial legumes are among the most important forages and many cultivars have been developed and are grown throughout the tropics. In terms of total and average costs, the manipulation of perennial legumes is very comparable to the annual legumes. Regeneration is the operation that requires the highest investment of resources. In 2007 the average cost of regenerating one accession of perennial grass was about US$ 76, while the total operational costs added to US$ 49,000. In this year there were no accessions characterized. The costs of seed health testing, viability testing and distribution is also very similar to the case of annual legumes.

Fodder trees are also important forages especially in dry environments. A wide range of leguminous tree species are cut and fed as livestock feed and browsed by free ranging livestock. For manipulation purposes these materials are classified in fodder tress that produce seed in less than 3 years, and fodder tress that require more than 3 years to produce seed. In total, ILRI genebank holds more than 3,000 accessions of fodder trees. In 2007, the genebank invested above US$ 50,000 in the conservation of fodder tree accessions (not included expenses in capital inputs). Regeneration was the most expensive operation (US$ 76/accession) in the case of fodder tress producing seed in less than 3 years, while for the fodder trees that produce seed only after three years in the field the most expensive operation was seed health testing (US$ 70 / accession). Note that in the last case (fodder trees >3 years) there were only 2 accessions tested for seed health.

The ILRI genebank also conserves accession of other forages classified as either "other annual or "other perennial. Main examples of this category include non-leguminous trees and shrubs and drought tolerant species such as Atriplex. These materials are in dry areas and are often grazed in traditional systems and rangelands. The total investment of ILRI in the conservation of these materials was above US$ 4,000.

Table 7.2. Operational Costs of ILRI Genebank: ANNUAL GRASSES – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	302	10.26	1,900.69	28.31	51.32	**0.03**	**6.29**	**0.09**	**0.17**	**6.56**
Long term storage	128	127.69	343.14	10.22	14.09	**1.00**	**2.68**	**0.08**	**0.11**	**2.87**
Medium term storage	1,051**	2,173.46	476.61	726.59	264.81	**2.07**	**0.45**	**0.69**	**0.25**	**1.40**
Germination testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Regeneration	38	240.16	975.40	1,319.80	576.24	**6.32**	**25.67**	**34.73**	**15.16**	**75.56**
Seed processing	6	189.18	114.24	0.00	2.12	**31.53**	**19.04**	**0.00**	**0.35**	**19.39**
Seed health testing	22	306.31	459.27	54.51	24.81	**13.92**	**20.88**	**2.48**	**1.13**	**24.48**
Distribution	316	675.80	3,540.05	9.00	1,223.60	**2.14**	**11.20**	**0.03**	**3.87**	**15.10**
Information management	1,046	633.71	2,513.75	518.60	30.37	**0.61**	**2.40**	**0.50**	**0.03**	**2.93**
General management	1,046	755.10	0.00	14.91	411.53	**0.72**	**0.00**	**0.01**	**0.39**	**0.41**
Total***	**N.A.**	**5,111.68**	**10,323.14**	**2,681.96**	**2,598.90**	**58.34**	**88.62**	**38.61**	**21.47**	**148.70**

(*) Operational costs, do not include capital costs.
(**) Medium term storage (MTS) is a very important activity for ILRI. This is the total number of accession on MTS. In 2007 no new accessions were added to MTS.
(***) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 7.3. Operational Costs of ILRI Genebank: PERENNIAL GRASSES – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/**acc**)	Average quasi-fixed cost (US$/**acc**)	Average variable labor cost (US$/**acc**)	Average non-labor costs (US$/**acc**)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Long term storage	648	646.44	1,737.16	51.75	71.33	**1.00**	**2.68**	**0.08**	**0.11**	**2.87**
Medium term storage	3,384**	6,977.95	1,530.17	2,332.75	850.19	**2.06**	**0.45**	**0.69**	**0.25**	**1.39**
Germination testing	3	63.56	52.43	38.39	166.80	**21.19**	**17.48**	**12.80**	**55.60**	**85.87**
Regeneration	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed processing	8	252.24	152.32	2.60	2.83	**31.53**	**19.04**	**0.33**	**0.35**	**19.72**
Seed health testing	68	946.78	1,419.57	777.60	720.00	**13.92**	**20.88**	**11.44**	**10.59**	**42.90**
Distribution	15	32.08	168.04	1.68	58.08	**2.14**	**11.20**	**0.11**	**3.87**	**15.19**
Information management	3,372	2,042.91	8,103.59	706.47	97.92	**0.61**	**2.40**	**0.21**	**0.03**	**2.64**
General management	3,372	2,434.23	0.00	48.08	1,326.64	**0.72**	**0.00**	**0.01**	**0.39**	**0.41**
Total* **	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

(*) Operational costs, do not include capital costs.
(**)Medium term storage (MTS) is a very important activity for ILRI. This is the total number of accession on MTS. In 2007 a total of 1439 accessions were added to MTS.
(***) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 7.4. Operational Costs of ILRI Genebank: ANNUAL LEGUMES – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	589	9,976.12	13,864.52	11,089.62	5,478.08	**16.94**	**23.54**	**18.83**	**9.30**	**51.67**
Safety duplication	1,211	41.15	7,621.64	113.52	205.77	**0.03**	**6.29**	**0.09**	**0.17**	**6.56**
Long term storage	1,285	1,281.90	3,444.83	102.61	141.45	**1.00**	**2.68**	**0.08**	**0.11**	**2.87**
Medium term storage	3,658**	7,549.91	1,655.60	2,523.96	919.88	**2.06**	**0.45**	**0.69**	**0.25**	**1.39**
Germination testing	567	12,012.87	9,909.38	7,255.77	136.67	**21.19**	**17.48**	**12.80**	**0.24**	**30.51**
Regeneration	358	2,262.60	9,189.28	12,433.94	5,428.82	**6.32**	**25.67**	**34.73**	**15.16**	**75.56**
Seed processing	236	7,441.15	4,493.30	76.74	83.58	**31.53**	**19.04**	**0.33**	**0.35**	**19.72**
Seed health testing	289	4,023.81	6,033.15	3,304.81	987.48	**13.92**	**20.88**	**11.44**	**3.42**	**35.73**
Distribution	997	2,132.18	11,169.07	111.35	3,860.54	**2.14**	**11.20**	**0.11**	**3.87**	**15.19**
Information management	3,684	2,231.93	8,853.39	771.84	106.98	**0.61**	**2.40**	**0.21**	**0.03**	**2.64**
General management	3,684	2,659.46	0.00	52.53	1,449.39	**0.72**	**0.00**	**0.01**	**0.39**	**0.41**
Total* **	**N.A.**	**51,613.09**	**76,234.16**	**37,836.68**	**18,798.63**	**96.46**	**129.63**	**79.32**	**33.30**	**242.25**

(*) Operational costs, do not include capital costs.
(**) Medium term storage (MTS) is a very important activity for ILRI. This is the total number of accession on MTS. In 2007 no new accessions were added to MTS.
(***) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 7.5. Operational Costs of ILRI Genebank: PERENNIAL LEGUMES – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	1,624	55.18	10,220.93	152.23	275.95	**0.03**	**6.29**	**0.09**	**0.17**	**6.56**
Long term storage	2,027	2,022.11	5,433.98	161.87	223.12	**1.00**	**2.68**	**0.08**	**0.11**	**2.87**
Medium term storage	6,870**	14,146.54	3,102.15	4,729.24	1,723.61	**2.06**	**0.45**	**0.69**	**0.25**	**1.39**
Germination testing	350	7,415.35	6,116.90	4,478.87	341.69	**21.19**	**17.48**	**12.80**	**0.98**	**31.25**
Regeneration	652	4,120.71	16,735.78	22,645.05	9,887.12	**6.32**	**25.67**	**34.73**	**15.16**	**75.56**
Seed processing	350	11,035.61	6,663.80	113.80	123.96	**31.53**	**19.04**	**0.33**	**0.35**	**19.72**
Seed health testing	203	2,826.42	4,237.82	2,321.37	679.83	**13.92**	**20.88**	**11.44**	**3.35**	**35.66**
Distribution	878	1,877.69	9,835.95	98.06	3,399.76	**2.14**	**11.20**	**0.11**	**3.87**	**15.19**
Information management	6,829	4,137.32	16,411.46	1,430.75	198.30	**0.61**	**2.40**	**0.21**	**0.03**	**2.64**
Total* **	6,829	4,929.82	0.00	97.37	2,686.72	**0.72**	**0.00**	**0.01**	**0.39**	**0.41**

(*) Operational costs, do not include capital costs.
(**) Medium term storage (MTS) is a very important activity for ILRI. This is the total number of accession on MTS. In 2007 no new accessions were added to MTS.
(***) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 7.6. Operational Costs of ILRI Genebank: FODDER TREES < 3years – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	711	24.16	4,474.80	66.65	120.81	**0.03**	**6.29**	**0.09**	**0.17**	**6.56**
Long term storage	828	826.00	2,219.70	66.12	91.14	**1.00**	**2.68**	**0.08**	**0.11**	**2.87**
Medium term storage	2,708**	5,567.10	1,220.79	1,861.10	678.29	**2.06**	**0.45**	**0.69**	**0.25**	**1.39**
Germination testing	44	932.22	768.98	563.06	304.18	**21.19**	**17.48**	**12.80**	**6.91**	**37.19**
Regeneration	200	1,264.02	5,133.67	6,946.34	3,032.86	**6.32**	**25.67**	**34.73**	**15.16**	**75.56**
Seed processing	147	4,634.96	2,798.79	47.80	52.06	**31.53**	**19.04**	**0.33**	**0.35**	**19.72**
Seed health testing	67	932.86	1,398.69	766.17	203.45	**13.92**	**20.88**	**11.44**	**3.04**	**35.35**
Distribution	26	55.60	291.27	2.90	100.68	**2.14**	**11.20**	**0.11**	**3.87**	**15.19**
Information management	2,304	1,395.87	5,536.97	482.71	66.90	**0.61**	**2.40**	**0.21**	**0.03**	**2.64**
General management	2,304	1,663.25	0.00	32.85	906.46	**0.72**	**0.00**	**0.01**	**0.39**	**0.41**
Total* **	**N.A.**	**17,296.03**	**23,843.68**	**10,835.69**	**5,556.84**	**79.51**	**106.09**	**60.49**	**30.29**	**196.87**

(*) Operational costs, do not include capital costs.
(**) Medium term storage (MTS) is a very important activity for ILRI. This is the total number of accession on MTS. In 2007 no new accessions were added to MTS.
(***) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 7.7. Operational Costs of ILRI Genebank: FODDER TREES > 3years – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	126	4.28	793.00	0.75	21.41	**0.03**	**6.29**	**0.01**	**0.17**	**6.47**
Long term storage	84	83.80	225.19	6.71	9.25	**1.00**	**2.68**	**0.08**	**0.11**	**2.87**
Medium term storage	831**	1,715.89	376.27	573.63	209.06	**2.06**	**0.45**	**0.69**	**0.25**	**1.39**
Germination testing	2	42.37	34.95	25.59	1.83	**21.19**	**17.48**	**12.80**	**0.91**	**31.19**
Regeneration	188	1,188.18	4,825.65	6,529.56	2,850.89	**6.32**	**25.67**	**34.73**	**15.16**	**75.56**
Seed processing	68	2,144.06	1,294.68	22.11	24.08	**31.53**	**19.04**	**0.33**	**0.35**	**19.72**
Seed health testing	2	27.85	41.75	22.87	34.74	**13.92**	**20.88**	**11.44**	**17.37**	**49.68**
Distribution	157	335.76	1,758.82	17.54	607.93	**2.14**	**11.20**	**0.11**	**3.87**	**15.19**
Information management	1,256	760.94	3,018.42	263.15	36.47	**0.61**	**2.40**	**0.21**	**0.03**	**2.64**
General management	1,256	1,663.25	0.00	17.91	494.15	**1.32**	**0.00**	**0.01**	**0.39**	**0.41**
Total* **	**N.A.**	**7,966.38**	**12,368.74**	**7,479.80**	**4,289.80**	**80.13**	**106.09**	**60.40**	**38.63**	**205.12**

(*) Operational costs, do not include capital costs.
(**) Medium term storage (MTS) is a very important activity for ILRI. This is the total number of accession on MTS. In 2007 no new accessions were added to MTS.
(***) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 7.8. Operational Costs of ILRI Genebank: OTHER ANNUAL – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	2	33.87	47.08	37.66	18.60	**16.94**	**23.54**	**18.83**	**9.30**	**51.67**
Safety duplication	8	0.27	50.35	26.01	16.28	**0.03**	**6.29**	**3.25**	**2.04**	**11.58**
Long term storage	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Medium term storage	138**	266.92	58.53	89.23	32.52	**1.93**	**0.42**	**0.65**	**0.24**	**1.31**
Germination testing	2	42.37	34.95	25.59	1.22	**21.19**	**17.48**	**12.80**	**0.61**	**30.88**
Regeneration	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Seed processing	3	94.59	57.12	0.98	1.06	**31.53**	**19.04**	**0.33**	**0.35**	**19.72**
Seed health testing	2	27.85	41.75	22.87	76.91	**13.92**	**20.88**	**11.44**	**38.46**	**70.77**
Distribution	3	6.42	33.61	0.34	11.62	**2.14**	**11.20**	**0.11**	**3.87**	**15.19**
Information management	138	83.61	331.64	28.91	4.01	**0.61**	**2.40**	**0.21**	**0.03**	**2.64**
General management	138	906.70	0.00	1.97	54.29	**6.57**	**0.00**	**0.01**	**0.39**	**0.41**
Total***	**N.A.**	**1,462.60**	**655.03**	**233.55**	**216.52**	**94.86**	**101.26**	**47.62**	**55.29**	**204.16**

(*) Operational costs, do not include capital costs.
(**) Medium term storage (MTS) is a very important activity for ILRI. This is the total number of accession on MTS. In 2007 no new accessions were added to MTS.
(***) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Table 7.9. Operational Costs of ILRI Genebank: OTHER PERENNIAL – 2007

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Characterization	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Safety duplication	278	9.43	1,746.58	11.81	137.43	**0.03**	**6.29**	**0.04**	**0.50**	**6.83**
Long term storage	3	2.99	8.04	0.24	0.33	**1.00**	**2.68**	**0.08**	**0.11**	**2.87**
Medium term storage	116**	228.79	50.17	76.48	27.88	**1.97**	**0.43**	**0.66**	**0.24**	**1.33**
Germination testing	0	0.00	0.00	0.00	0.61	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Regeneration	9	56.88	231.02	312.59	136.48	**6.32**	**25.67**	**34.73**	**15.16**	**75.56**
Seed processing	4	126.12	76.16	1.30	1.42	**31.53**	**19.04**	**0.33**	**0.35**	**19.72**
Seed health testing	0	0.00	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Distribution	1	2.14	11.20	0.34	3.87	**2.14**	**11.20**	**0.34**	**3.87**	**15.41**
Information management	116	70.28	278.77	24.30	3.37	**0.61**	**2.40**	**0.21**	**0.03**	**2.64**
General management	116	99.62	0.00	1.97	45.64	**0.86**	**0.00**	**0.02**	**0.39**	**0.41**
Total**	**N.A.**	**596.25**	**2,401.94**	**429.03**	**357.02**	**44.46**	**67.72**	**36.40**	**20.66**	**124.78**

(*) Operational costs, do not include capital costs.
(**) Medium term storage (MTS) is a very important activity for ILRI. This is the total number of accession on MTS. In 2007 no new accessions were added to MTS.
(***) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

SECTION 8

Conservation and Management of Rice Genetic Resources in the IRRI Genebank

D. Horna, R. Sackville-Hamilton, S. Almazan, F. Guzman, R. Reaño, G. L. Capilit

Rice is one of the main cereals produced and consumed in the world. Rice cultivation is believed to have spread from the foothills of the Himalayas southwest into the Indian subcontinent, into Southeast Asia, and eastward into China and Japan. Farmers only plant two species from the genus *Oryza*: *O. sativa*, originating in Asia and now grown worldwide and *O. glaberrima*, which is grown in West Africa. More than 20 species of wild rice are scattered across tropical Asia, Africa, and Latin America and the Caribbean. Wild rice species grow in many different habitats, from sunny open lands to shady forests. Breeders use wild species for traits not found in cultivated rice. Since 1962, the International Rice Research Institute (IRRI) has been at the forefront of international collaborative efforts to systematically collect, conserve, characterize, and share traditional rice varieties and wild rice species. Constructed in 1977--and significantly renovated and upgraded in 1994--the International Rice Genebank (IGB) at IRRI has international-standard facilities for medium- and long -term storage of rice seeds at subzero temperatures, a seed-drying room, and screenhouses for multiplying and maintaining wild rice species and low seed stock germplasm[27].

Currently the IRG holds in trust more than 110,000 accessions (Jackson 1997). This is the most complete rice collection in the world covering most of the available diversity. In addition to cultivated rice (*O. sativa* and *O. glaberrima*) the IRG holds a number of wild rice and related genera accessions. This study evaluates the cost effectiveness of conserving and distributing rice accessions. A previous evaluation carried out by Koo *et al.* (2004) serves as a baseline for this study. The evaluation focuses on the two main types of materials held at the genebank: cultivated and wild rice. These materials are

[27] http://beta.irri.org/seeds/index.php?option=com_wrapper&Itemid=7

mainly propagated by seed which facilitates the flow of operations, but a number of the wild materials require special facilities for regeneration and multiplication.

The main challenges for the IRRI genebank with implications on the genebanks cost effectiveness are the large number of accessions manipulated and the large demand for rice materials. As a consequence, the use of temporary labor for regular operations is a key input in the genebank performance. Moreover, the accessions held at the genebank of cultivated and wild rice belong to different agro-ecologies and require different conditions for their regeneration and for other operations. Regeneration under not optimal agro-ecological conditions has implications on the total amount of seed produced. In general, few accessions have a high demand and the rest of the materials have a lower demand, but this can change due to eventualities, like the outbreak of diseases. The IRG therefore needs to have a minimum volume stored to be able to satisfy the demand of the genebank users in the public and private sector.

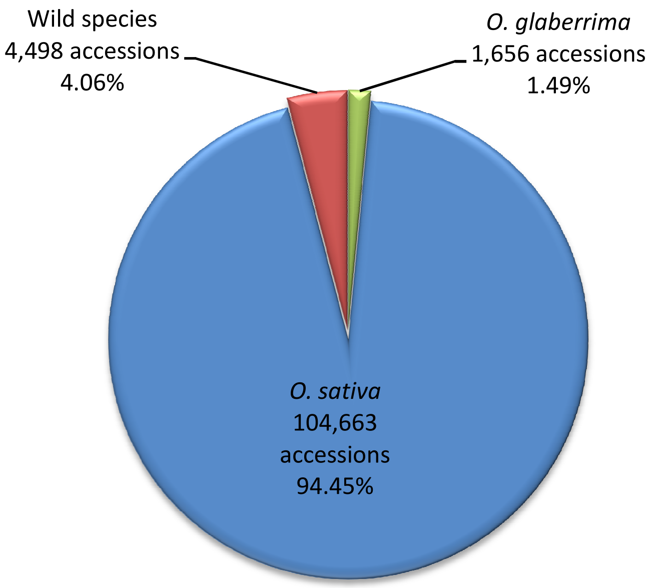
8.1. Data

The information collected for the genebank at IRRI corresponds to years 2006, 2007 and 2008. The data collected corresponds to accessions manipulated per operation, inputs use (capital, quasi-fixed, labor variable and non-labor variable) and related costs. The estimation of variable non-labor costs might be on the lower range as it is more difficult to account for small office, field and laboratory expenses that are small but regular and can become considerable on an annual basis. Also, due to the confidentiality of the information, the quasi-fixed labor has been estimated using averages values per type of staff rather than actual values[28]. Note that, the estimation of total and averages costs are actual genebank costs rather than annual expenditures. The difference can be substantial since the actual costs are related to number of accessions manipulated while actual expenditures could be higher than that. When doing a requisition genebank staff usually order in large quantities that can last for more than one year.

Rice (cultivated rice) represents 96% of the accessions conserved in the IRG (Figure 8.1). As mentioned above the accessions belong to two species: *O. sativa* and *O. glaberrima*, being *O. sativa* the species with the highest representation (98% of cultivated materials).

[28] According to the genebank manager, the value estimated by the tool show a downward bias.

Figure 8.1. Type of accessions at the International Rice Genebank at IRRI according to type of material



Source: IRG Information and documentation (2009)

8.2 Results

Total and average costs of genebank operations in 2008 are reported in Tables 8.1 and 8.2 for rice and wild rice.

The *ex-situ* conservation of cultivated rice follows the standard procedure for conservation of materials propagated by seed (Rao *et al.* 2006). It is possible however that some accessions of *O. glaberrima* require special conditions to germinate. Some *O. glaberrima* accessions are closer to wild materials than to cultivated ones. Table 8.1 presents the summary of total and average costs of conserving and managing cultivated rice accessions in the IRG in 2008. Note that 2008 is a particular year for the IRG because the genebank was very involved in the multiplication, seed processing and all the other operations leading to send duplicates to the collection in Svalbard. In this year, the total operational costs (not including capital) for safety duplication recorded the second largest investment (US 64,000) across operations. The average costs of safety duplication (US$ 29/accession) seem to be high, but this is probably due to the fact that here it is only reported the total number of accessions that were ready to be sent. Since each operation in the genebank depends on other operations, there are always lags in the total number of accessions manipulated per operation. These lags have implication on the estimation of average costs per operation.

Also note that medium and long term average storage costs are estimated using the additional number of accessions stored and not the total number of accession in storage. This leads to higher average costs but reflects the value of adding one accession to the genebank each year. Since in 2008 a new cold room was built the total and average capital cost of long term storage were relatively high (US$ 35/accession) but the average operational costs were within the normal range (US$ 8.13/ accession). In terms of total costs general management required the highest investment in the IRG (US$ 91,000) and this is understandable given the size of operations in this genebank that requires a large logistic coordination. Other operations that demanded high investments from the IRG were information management (US$ 83,000), distribution (US$ 73,000), regeneration (US$ 66,000) and characterization. Distribution of materials is one of the most important operations in the genebank. In 2008 the IRG sent a total of 18,159 accessions to private and public users. Regeneration and characterization tend to be across crops and across centers the operations with the highest average costs. Cultivated rice is not the exception in this tendency. In 2008 a total of 3467 accessions of cultivated rice were regenerated, at an average costs of US$ 19 / accession. In the same year a total of 2,216 accessions were characterized at an average costs of (US29/accession). Seed health is performed by the seed health laboratory of IRRI. Since 2008 there is a fixed charge per screening activity that is performed on each accession. The services include some expenses of seed distribution (packing and shipping). This year, the average cost per accession was US$ 15.81.

Wild rice accessions in comparison record higher average costs per operation mainly for characterization (US 133/ accession) and regeneration (US$ 92/accession). This is a tendency not only for 2008 for in general. Wild materials need to be manipulated under special conditions in order to get the amount of seed needed for storing and distribution. The IRG has a special unit for the regeneration and evaluation of wild rice. Quite often however, despite these special conditions, some accessions do not germinate or produce seed. In those cases the accessions are sent to the phytotron. The phytotron is a special chamber when humidity and temperature conditions can be controlled and thus it can replicate the environmental conditions where more suitable for the multiplication of this fragile materials. Some cultivated materials, mainly *O. glaberrima*, need to be treated in the phytotron. The amount of seed produced by wild materials is normally very low compared to the cultivated materials and thus in 2008 there was no screening of wild rice for seed health (Table 8.2).

In comparison to the estimations from Koo et al. (2004), our estimations reflect actual costs per year. There are some significant differences in average costs, but the total costs are similar. The differences in average costs are probably due to:

- We have disaggregated the costs of seed processing from the costs of regeneration and characterization. As a consequence our regeneration cost would probably tend to be smaller that the estimations from Koo et al.
- We have as well disaggregated the costs of general management and information management from the costs of all the other operations.
- We are using actual input use; therefore our estimations are actual annual costs rather than best estimations.
- The costs for wild materials have been estimated separately for all operations. Koo et al. did separate estimations only for regeneration and characterization.

The availability of information for several years (2006, 2007 and 2008) allows formulating some initial conclusions about the performance of the IRG across the years. Figures 8.2 to 8.3 summarize this behavior for total and average costs of the different operations for cultivated and wild rice. Table 8.3 presents the number of accessions manipulated per operation across these years. This number has strong implications on the final average costs reported.

Table 8.1. Operational Costs of IRRI Genebank: RICE – 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	2,899	103.65	4,211.15	65.19	241.34	0.04	1.45	0.02	0.08	**1.56**
Characterization	2,216	3,524.92	26,306.60	5,653.48	32,422.47	1.59	11.87	2.55	14.63	**29.05**
Safety duplication	1,300	270.82	7,528.03	814.90	302.56	0.21	5.79	0.63	0.23	**6.65**
Long term storage	676	23,952.96	4,954.15	437.82	100.57	35.43	7.33	0.65	0.15	**8.13**
Medium term storage	2,820	10,131.97	5,625.85	437.82	1,115.66	3.59	1.99	0.16	0.40	**2.55**
Germination testing	17,980	35,645.85	18,817.61	2,274.50	417.31	1.98	1.05	0.13	0.02	**1.20**
Regeneration	3,467	2,542.00	22,801.27	13,305.76	30,309.65	0.73	6.58	3.84	8.74	**19.16**
Seed processing	4,357	17,113.99	28,099.94	3,596.38	2,341.75	3.93	6.45	0.83	0.54	**7.81**
Seed health testing	3,840	880.46	10,991.34	1,407.28	48,318.21	0.23	2.86	0.37	12.58	**15.81**
Distribution	18,159	669.26	25,304.13	1,563.64	46,217.69	0.04	1.39	0.09	2.55	**4.02**
Information management	106,319	795.01	43,759.43	0.00	40,193.22	0.01	0.41	0.00	0.38	**0.79**
General management	106,319	5,648.36	73,363.48	0.00	17,646.94	0.05	0.69	0.00	0.17	**0.86**
Total	**N.A.**	**101,279.25**	**271,762.98**	**29,556.76**	**219,627.37**	**47.83**	**47.87**	**9.25**	**40.47**	**97.58**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

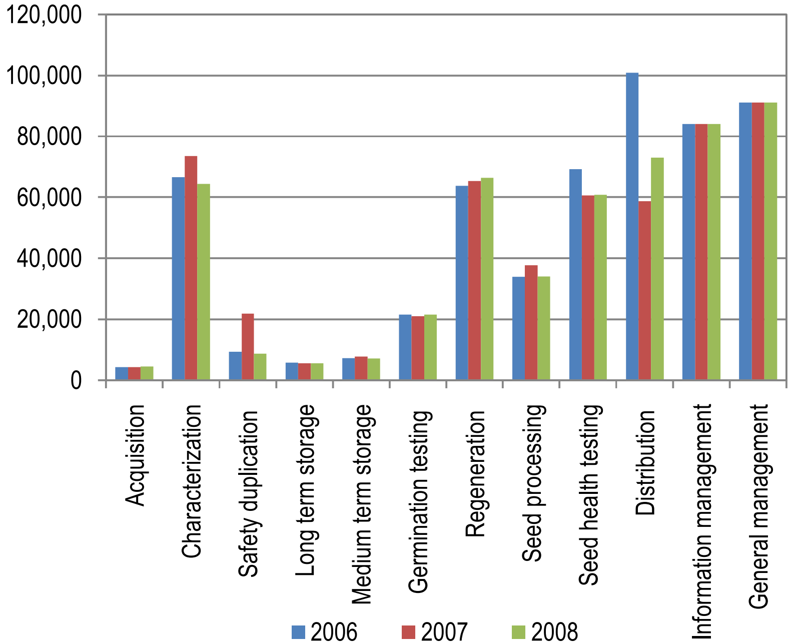
Table 8.2. Operational Costs of IRRI Genebank: WILD RICE – 2008

Activities	No. access.	Total capital cost (US$)	Total quasi-fixed cost (US$)	Total labor variable costs (US$)	Total non-labor costs (US$)	Average capital cost (US$/acc)	Average quasi-fixed cost (US$/acc)	Average variable labor cost (US$/acc)	Average non-labor costs (US$/acc)	Total AC*
Acquisition	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Characterization	407	18,359.75	16,500.69	941.35	36,722.88	45.11	40.54	2.31	90.23	133.08
Safety duplication	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long term storage	0	0.00	0.00	18.52	0.00	0.00	0.00	0.00	0.00	0.00
Medium term storage	23	82.64	45.88	18.52	9.10	3.59	1.99	0.81	0.40	3.20
Germination testing	57	113.00	904.60	7.21	1.32	1.98	15.87	0.13	0.02	16.02
Regeneration	500	21,082.83	14,717.88	941.35	30,556.74	42.17	29.44	1.88	61.11	92.43
Seed processing	500	1,806.55	5,601.34	152.15	268.73	3.61	11.20	0.30	0.54	12.04
Seed health testing	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Distribution	3,251	119.82	4,757.17	66.15	8,835.58	0.04	1.46	0.02	2.72	4.20
Information management	4,498	33.63	7,397.55	0.00	1,700.44	0.01	1.64	0.00	0.38	2.02
General management	4,498	238.96	3,022.87	0.00	746.58	0.05	0.67	0.00	0.17	0.84
Total	**N.A.**	**41,837.19**	**52,947.99**	**2,145.25**	**78,841.37**	**96.56**	**102.83**	**5.45**	**155.56**	**263.84**

(*) Operational costs, do not include capital costs.
(**) The total cost values do not reflect the total cost of conservation of this material it just report how much in average the genebank spent that year on this type of material.

Figure 8.2. Performance of total costs and average cost per operation for RICE in the IRG at IRRI

a) **Total Costs**



b) **Average Costs**

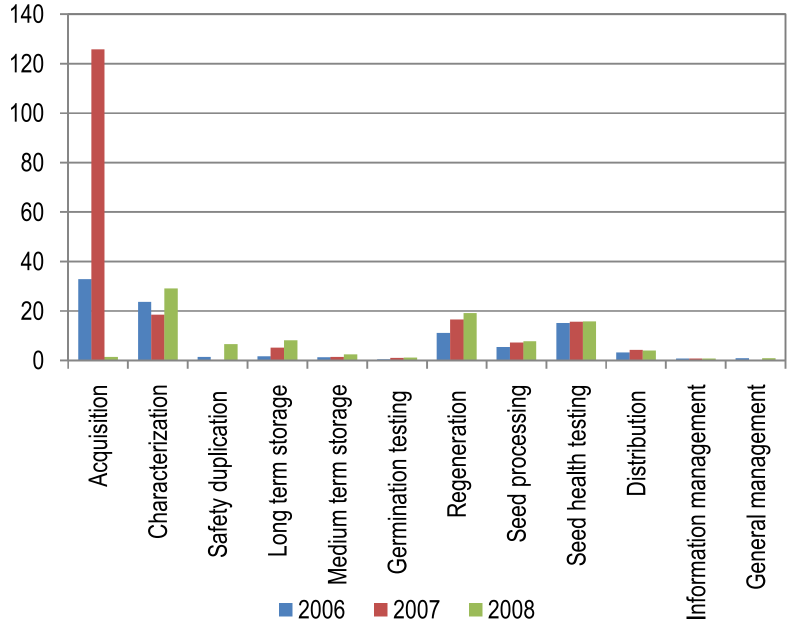


Figure 8.3. Performance of total costs and average cost per operation for WILD RICE in the IRG at IRRI

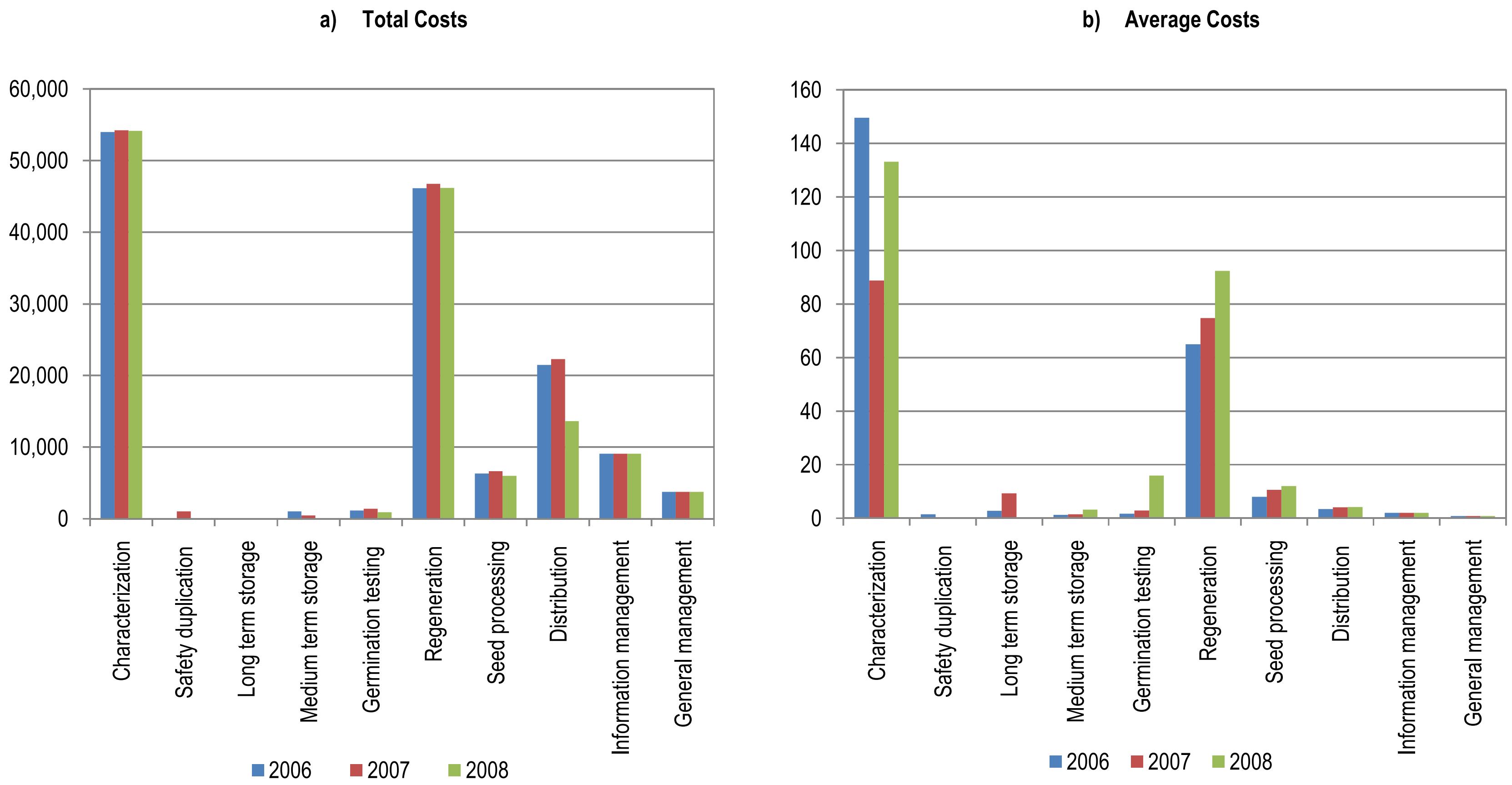


Table 8.3. Number of accessions manipulated per operation and per type of material 2006-2008

Operations	Rice			Wild Rice		
	2006	**2007**	**2008**	**2006**	**2007**	**2008**
Acquisition	130	34	2,899	0	0	0
Characterization	2,812	3,973	2,216	361	611	407
Safety duplication	6,110	67,076	1,300	42	3,104	0
Long term storage	3,220	1,060	676	15	4	0
Medium term storage	5,336	5,017	2,820	784	320	23
Germination testing	45,674	18,911	17,980	702	485	57
Regeneration	5,685	3,924	3,467	710	626	500
Seed processing	6,310	5,172	4,357	786	626	500
Seed health testing	4,560	3,840	3,840	0	0	0
Distribution	30,765	13,575	18,159	6,419	5,347	3,251
Information management	106,106	106,193	106,319	4,495	4,498	4,498
General management	106,106	106,193	106,319	4,495	4,498	4,498

SECTION 9

Costs Effectiveness of Germplasm Collections in the CG system

D. Horna, D. Debouck, D. Dumet, J. Hanson, V. M. Manyong, T. Payne, R. Sackville-Hamilton, I. Sanchez, S. Taba, H. D. Upadhyaya, I. van den Houwe

Cost information is useful to monitor the performance of the genebanks. Thus, managers, users, and donors of the genebanks can have an idea of the relative costs of managing plant genetic resources. This information can be used to make users but especially donors aware of the actual costs of conserving and distributing accessions and in this way facilitate fund raising. Managers however do have an idea of genebank operational costs. What is then the added value of using a periodic system to collect costs information for the genebank manager? In this section we present some specific cases where the information collected in the genebanks visited can help in the decision process. It is true that the current amount of information does not allow us to make conclusions across centers, but it does allow for some analysis within the centers.

1. Rationalization

Rationalization within a genebank and across genebanks is recurrent discussion in the CG system. The information collected in this evaluation can help to address partially some of the main points raised for an informed decision about rationalization.

a) <u>Duplication and molecular characterization</u>

One of the goals of a genebanks is to conserve unique genetic material[29], however duplication is often unavoidable. Duplication of genetic material is associated with costs inefficiencies, as the material has to be periodically regenerated, tested, or stored. The costs are particularly high for materials that are conserved in-vitro. The real problem of eliminating and avoiding duplication relies on the difficulty to actually find the duplicated material. While molecular techniques are becoming more affordable it is still expensive to do a full screening to determine if an accession is a duplicate or not. But, is

[29] We do not discuss here the underlying concept diversity and of what constitutes a unique material as there might be different points of view and ways to measure it. Nevertheless

it actually less expensive to eliminate duplication than actually keeping the duplicates? What are the steps necessary to eliminate duplication and what kind of resources are needed?

Note that the cost of conserving a duplicate depends on the material under evaluation (size, multiplication method, storing method, level of domestication). Moreover, the proportion of duplicates in the collection can considerably affect genebank costs. Take as an example the case of the European Genebank Integrated System (AEGIS) which goal is to create an integrated genebank system for conserving the genetically unique and important accessions of Europe and making them available for breeding and research (ECPGR 2008). The level of duplication across European genebanks participating on this initiative has been estimated around 35% or higher. AEGIS is expected to increase the long-term costs effectiveness of the collection management by controlling redundancy and duplicates more effectively. A reduction of the high duplication level can lead to a considerable cut on operational costs across the system. In the case of the CG system this value is probably lower across collections as different genebanks have different crops mandates. With the exemption of some materials[30], there is however no information available about the level of duplication within each genebank, or the information is very limited.

In CIAT a new material of cassava that is going to be added to the collection is subject to a molecular and biochemical characterization. Assessing the costs incurred in performing this operation can provide useful information and help in the decision of discarding materials Vs maintaining long-term expenses by keeping a duplicate in the collection. In other words the costs information generated by the operation can help to conclude on avoiding duplication. Notice that avoiding and eliminating duplication are different concepts. Using CIAT's information as an example, the additional annual cost of using molecular and biological characterization techniques to identify duplicates and add them to the collection (US$ 108.7 per accession) is presented in Table 9.1. In in-perpetuity terms, the additional cost of non –identifying a duplicate would be equal to the cost of

[30] At CIAT, although the level of internal duplication varies from crop to crop the level of internal duplication for cassava is around 8%, and with a specific research going on in tracking these internal genetic copies. In common bean the level of internal duplication may be around 5-6%, higher in Central America (15-18%), lower in the Andes (3%), intermediate in southern Europe and Africa (10%).

conserving and distributing this material as a different accession. In other words this would add US$ 1,313.71 per accession to the total genebank in-perpetuity costs. It is important to mention that the molecular characterization is carried out once the passport data have been checked throughout carefully. In other words, molecular characterization is done when there are suspicions that materials are genetic copies of each other.

IITA is presently working on molecular finger printing of the yam and cassava collection. This is to reduce the level of duplicates and also guide future collecting mission /acquisition from National genebank.

Table 9.1. Molecular characterization costs vs. cost of conserving a duplicate

Goal	Average Annual Costs		Average In-Perpetuity Costs
	Without Characterization	With Characterization	Without Characterization
Conservation	90.85	144.89	542.52
Distribution	47.65	101.69	771.19
TOTAL	138.51	246.58	1,313.71
Additional		108.07	1,313.71

b) <u>When location does not matter: Outsourcing</u>

Some operations performed by a genebank could be or "outsourced" (done by a third party). These operations tend to be related to laboratory analysis like viability testing or molecular characterization. Long-term storage of seed germplasm could as well be outsourced since the location of the storing facilities would not affect the quality of the operation. A comparison of operating costs of viability testing in different materials with a reference value by a private laboratory is useful for an analysis of potential advantages and disadvantages of having this operation outsourced. Staff qualification, costs of transportation, availability of the information, and timing of the operation within the flow of the genebank operation are crucial factors to take into account for making a decision about outsourcing or doing it at home.

There are several laboratories around the world that provide germination and viability tests. If the service is going to be outsourced then it is important to select a laboratory that not only offers a good quality-to-price service but that it is also located within reasonable distance. Table 9.2 presents a quick comparison on germination costs across genetic materials in the CG system, and approximated fee charged by two international and accredited seed testing laboratories in the US and in the UK.

Table 9.2. Comparative costs of germination testing (US$)

Material	Own Genebank	IOWA State University, Seed Testing Laboratory (USA)	Seed Testing Station of the Science and Advice for Scottish Agriculture (UK)
Common bean / CIAT[1]	4.48	12	24.7
Tropical forages/ CIAT[1]	9.84	30	28.6*
Wheat / CIMMYT[2]	6.19	17	26.4
Maize /CIMMYT[2]	4.42	12	26.4
Sorghum, ICRISAT[2,3]	2.71	17	26.4
Groundnut, ICRISAT[2,3]	2.72	18	24.7
Chickpea, ICRISAT[2,3]	2.54	18	24.7
Annual legumes, ILRI[2]	27.59	30	28.6*
Perennial legumes, ILRI[2]	28.21	30	28.6*
Cowpea, IITA[1]	6.04	18	24.7
Rice, IRRI[1]	1.20	17	26.4
Wild rice, IRRI[1]	16.02	31	28.6*

[1] Information from 2008
[2] Information from 2007.
[3] Cost for wild materials tend to be higher. According to CIRSAT estimations wild chickpea testing costs US$12.56, wild Pigeonpea US$ 14. 30, Wild groundnut US$ 16.75, wild sorghum US$12.60, wild pearl millet US$ 14.60, and wild small millets US$ 10.40.
* Probably higher

In all the cases, the fees charged by the private laboratories are higher than the estimated costs for the CG genebanks. For instance, according to the estimations for 2007, the average cost of testing seed viability at the CIMMYT genebank was about US$ 6.19 per accession. This cost only includes operational costs. If capital costs are taken into account the total value increases to US$ 9. The International Seed Testing Association (ISTA) provides a list of accredited laboratories around the world that carry out these tests. The prices listed for these test in UK vary considerably across countries and laboratories. For instance, The Seed Testing Station of the Science and Advice for Scottish Agriculture[31] charges US$ 26.4 (£16.2) per sample for a basic germination test, and requires 7 – 14 days to provide the results. Germination test prices can be higher than that when other test are included, like 1000 seed weight and seed rate table, as in the case of the National

[31] Prices of 2008 can be found here: http://www.sasa.gov.uk/seed_testing/osts/test_fees.cfm

Institute of Agricultural Botany (NIAB) based in Cambridge that charges US$84.5 (£ 52) per sample.

To the fees reported by the private laboratories it is necessary to add the VAT and the costs of sending the materials. Since all the genebanks in the CG system have the laboratories and personnel trained to perform this operation, it is clear that the additional cost charged by the private laboratories does not justify the outsourcing of this operation. In addition to the higher costs there are also plant quarantine issues. Seed health testing is an expensive operation and it does not justify doing it for outsourcing germination evaluation.

2. Operations within the Genebank

a) Diversity and Economies of Scale

There are several genebanks in the CG system, like ICRISAT, ILRI and IITA that deal with multiple crops. The intricacy of the flow of operations increases with the number of crops or types of materials. This has implications on the operational costs and also on the possibilities for economies of scale. In the case of genebanks that deal only with seed propagated materials (ICRISAT, ICARDA) the effect on costs could be less remarkable. The combination of clonal and seed crops definitively adds to the complexity in the decision making, giving less scope for selection of cost effective practices. Table 9.3, shows the average general and information management costs for the genebanks included in this study.

We expected that average management costs would tend to be higher in centers with a larger diversity of materials not only in terms of number of species but also in terms of materials that required different conservation and regeneration practices. All genebanks hold in their collections materials that required special regeneration techniques such as wild materials, or materials that need to stay in the field for more than one season such as forages and other perennial crops like Musa. A few genebanks also have materials that require special storage techniques like in-vitro cultivation or cryopreservation such as cassava, musa or yam. The differences across materials and centers however have not been as drastic as expected.

But, would there be differences if we concentrate on the type of material and conservation technique? The conservation of clonal (cassava, musa, yam) and seed crops (cowpea, soybean, beans, etc.) is a distinct characteristic of CIAT and IITA genebanks. While it is difficult to compare costs across centers because of a number of considerations (location, agro-ecological conditions, labor costs, etc), the comparison among seed and clonal crops could be interesting for genebank managers. Table 9.4 provides this information.

Table 9.3. Comparing average general and information costs given the conservation technique required (US$/accession)

Genebank	No. Acc.	No. crops/crop types (No. of species/ taxa)	Materials	General Management Costs (US$)	Information Costs (US$)
CIAT	65,510	3 (795)	Clonal: Cassava, Seed: Beans, Tropical Forages	1.37	2.29
CIMMYT	148,561	2 (7)	Seed only: Rice, Wheat (Barley, Rye, Triticale, Teosintle, *Tripsacum*)	1.02	0.97
ICRISAT	118,882	6 (11)	Seed only: Sorghum, Groundnut, Chickpea, Pigeonpea, Pearl millet, Small millets (Foxtail millet)	1.17	0.31
IITA	28,433	7 (60*)	Seed: Bambara, maize, Cowpea, Soybean Clonal: Yam, cassava, musa,	1.58	1.61
ILRI	18,745	8 (750)	Seed: Annual legumes (3,658), perennial legumes (6,879), annual grasses (1,051), perennial grasses (3,370), fodder tress <3 years (2,708), fodder tress > 3 years (831), other annual (138), other perennial (116)	1.26	1.88
IRRI	110,817	2	Seed: Rice (*O. sativa, O. glaberrima*), Wild rice (XX)	0.86	0.84

(*) The exact number of available species is unknown

Table 9.4. Conservation of clonal and seed crops across centers

Genebank	Type of Material		Conservation Method	No. Accessions	General management costs ($/ acc)	Information management costs ($/ acc)
CIAT	Clonal	Cassava	• In vitro (MT) • Cryopreservation (LT) • Bonsai	6,467	1.37	1.54
	Seed	Beans	• Cold room (ST & LT)	35,903	1.37	2.25
		Tropical Forages	• Cold room (ST & LT) • Field genebanks (MT)	23,140	1.37	2.55
IITA	Clonal	Cassava	• In vitro (MT) • Cryopreservation (LT)	3,368	1.47	1.85
		Yam	• In vitro (MT & LT)	3,039	1.67	1.95
		Musa	• In vitro (MT) • Cryopreservation (LT)	173	1.47	1.45
	Seed	African yam bean	• Cold room (MT & LT)	152	1.47	1.45
		Bambara	• Cold room (MT & LT)	1,843	1.47	1.45
		Cowpea	• Cold room (MT & LT)	15,113	1.64	1.56
		Maize	• Cold room (MT & LT)	878	1.47	1.45
		Soybean	• Cold room (MT & LT)	1,751	1.47	1.45
		Wild Vigna	• Cold room (MT & LT)	1,516	1.47	1.45
		Mis. legumes	• Cold room (MT & LT)	600	1.47	1.45

Note: ST stands for short term storage; MT stands for medium term storage; LT stands for Long term storage

b) Cryopreservation and In-vitro conservation

Cryopreservation is still an operation under research for genebanks working with clonal crops. CIAT for example has only around 640 accessions of cassava under cryopreservation of more than 6,000 accessions held by the genebank. The development of the cryopreservation protocol is an on-going activity. While this operation has been proven to be effective, there is still some discussion about the need to guarantee the integrity of the material stored. Currently all the cassava accessions are stored in-vitro in CIAT, and safety duplication copies are sent to CIP for storage. Given the short storage life of the in-vitro materials the costs of storing and duplication are significant for the genebank. The most cost effective practice according to the cryopreservation expert in CIAT is therefore a combination of short term storage and distribution using in-vitro material, and a long term storage and duplication using cryopreservation techniques. Table 9.5 shows cost information that supports this statement[32]. Since these are average costs

[32] These figures however do not cost the risk of having problems with the integrity of the collection.

the difference across centers is given by the number of accession manipulated which is considerably lower in the case of IITA and thus the costs considerably higher. Note that CIAT and IITA do not use the same in vitro conservation process for cassava. CIAT system is less demanding as it requires only 1 subculture per year in comparison to IITA system which requires 1 to 2 subcultures per year. The genebank at IITA is adjusting the technology to CIAT standards to reduce the cost for cassava. It is important however to take into consideration the time to regenerate a full seeding from in vitro plant. The IITA strategy may provide a faster system *i.e.* request may be processed faster which also have some economic value.

Table 9.5. Average conservation cost for clonal crops for CIAT and IITA (US$/accession)

Genebank	Genetic Material	Total No. Access.	Cryopreservation		In-Vitro		Field Genebank	
			No. Access.	Cost ($/ acce.)	No. Access	Cos ($/ acce.)	No. Access	Cost ($/ acce.)
CIAT	Cassava	6.467	640	44.20	8,261	14.28		
IITA	Cassava	3,368	50	53.23	2,455	9.84	3,388	3.36
	Musa	173	36	26.55	230	8.24	482	3.32
	Yam	3,039			1,641	8.24	3,200	3.32

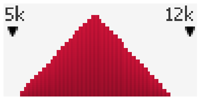
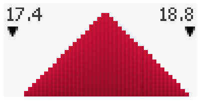
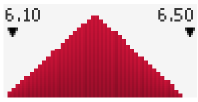
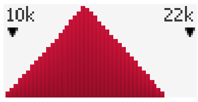
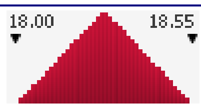
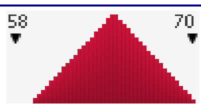
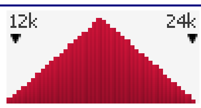
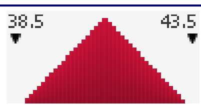
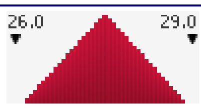
3. Financial Aspects

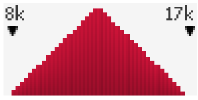
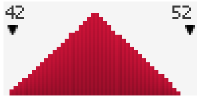
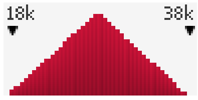
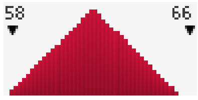
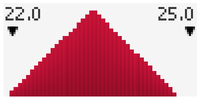
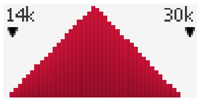
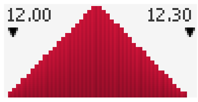
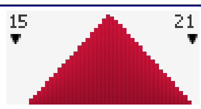
a) <u>Labor cost in Developing countries</u>

Genebanks make use of temporary and casual labor to accomplish several specific activities across operations. The use of casual labor is particularly intensive for field activities that are part of regeneration and characterization of materials. Seed cleaning is also a labor intensive activity. One of the advantages of being located in a developing country is the availability of comparatively cheap labor. In some countries however the cost of temporary labor has increased in the latest years, as a consequence of economic development or competition with stronger sectors of the economy.

Hyderabad is a city that is growing fast due to the computer and software industry. As a result of that demand for both qualified labor as well as temporary labor is increasing. This high labor demand creates possibilities for higher labor wages in the near future. Table 9.6 presents the results of a simulation for the ICRISAT genebank, assuming an increase that varies from 0% to 50% of current wages. The table presents the variation of total variable labor costs and the effect on the average regeneration and characterization costs. We can observe that despite the 100% variation the total average costs are not significantly affected, as they represent in average only 3 – 12% of the total operational costs. So, while there is a potential increase in labor the immediate effect on the average costs is not significant but it can be significant at the aggregate level, for instance when preparing the budget for the following year, and especially when the number of accessions manipulated is high.

Table 9.6. Simulating wage increase on total labor costs and average cost of regeneration and characterization, ICRISAT

Name	Graph	No. of Accessions	Actual labor Costs	50% Variation	100% Variation
Sorghum (Total variable labor Costs (US$)			**5,580.54**	**8,324.59**	**11,078.21**
• Characterization (Av. labor cost / accession, US$/acc)		2,377	17.55	18.15	18.75
• Regeneration (Av. labor cost / accession, US$/acc)		4,603	6.11	6.29	6.47
Pearl millet (Total variable labor Costs (US$)			**10,141.94**	**15,128.92**	**20,133.28**
• Characterization (Av. labor cost / accession, US$/acc)		2,094	18.04	18.28	18.53
• Regeneration (Av. labor cost / accession, US$/acc)		793	59.72	64.80	69.89
Chickpea (Total variable labor Costs (US$)			**12,032.05**	**17,948.44**	**23,885.44**
• Characterization (Av. labor cost / accession, US$/acc)		1,200	38.97	41.08	43.19
• Regeneration (Av. labor cost / accession, US$/acc)		1,650	26.29	27.55	28.80

Name	Graph	No. of Accessions	Actual labor Costs	50% Variation	100% Variation
Pigeonpea (Total variable labor Costs (US$)			**8,341.62**	**12,443.36**	**16,559.38**
• Characterization (Av. labor cost / accession, US$/acc)		798	42.33	46.78	51.25
Groundnut (Total variable labor Costs (US$)			**18,676.61**	**27,860.26**	**37,075.90**
• Characterization (Av. labor cost / accession, US$/acc)		900	58.23	61.75	65.28
• Regeneration (Av. labor cost / accession, US$/acc)		2,400	22.09	23.40	24.71
Small millets (Total variable labor Costs (US$)			**14,487.84**	**21,611.79**	**28,760.56**
• Characterization (Av. labor cost / accession, US$/acc)		1,737	12.01	12.15	12.29
• Regeneration (Av. labor cost / accession, US$/acc)		1,737	15.69	18.23	20.79

Note: We do not have information on labor use for Pigeonpea regeneration for this year (2007). All the casual labor was reported for characterization

b) Retirement and the need for a succession plan

In several of the genebanks of the CG system crop specialist or even genebank heads are reaching retirement ages. The expertise accumulated by genebank scientists has a significant effect on the performance of the genebank and thus on its cost effectiveness. Unfortunately, it is difficult to actually measure this effect and even more to cost experience. It is possible however to assume learning lags in the performance. Hiring a new scientist in charge of one operation in the genebank can cause a lag on the activities planned for the year and generate backlogs in most of the operations. Training of new staff is therefore necessary to avoid this lags. The training is understood as a period of overlapping of experts. This practice can save the genebank operational costs and backlogs.

c) <u>Exchange rate fluctuations</u>

Most of the genebanks of the CG system are located in developing countries where some of the operational expenses (supplies and labor) are paid in the local currency. Exchange rate fluctuations over the year can significantly affect the total expenses of the genebank and thus have negative impacts on the annual approved budgets. In 2008 for instance the fluctuation of the Colombian peso was above 700 units, equivalent to a 30% of the highest value[33] [34]. Similar tendencies but not as drastic has been observed in Philippines, where the fluctuation was around 20% in the same year.

On one hand the inflation rates of the countries can determine these fluctuations. On the other hand, as the food and financial crises have shown, global events can have severe impact on economies in development and thus affect exchange rates. Tables 9.7 and 9.8 below report some of potential effect of drastic exchange currency fluctuations in the total genebank expenses, as well as in the average costs of operations. These values are probably underestimated since most of the expenses in local currencies have been reported in US dollars, despite been executed in local currency.

[33] Source: OANDA (http://www.oanda.com/convert/fxhistory)
[34] See Annex 4 for a graphic representation of the fluctuation of Colombia peso from 2007 to 2009.

Table 9.7. Changes in Average and in perpetuity Costs due to Exchange Rate Fluctuations in 2008, CIAT Genebank

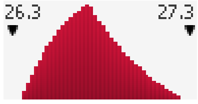
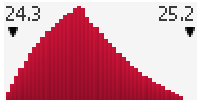
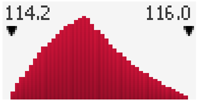
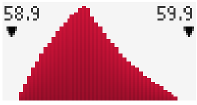
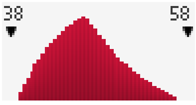
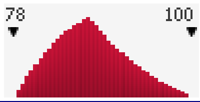
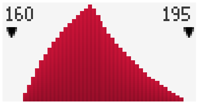
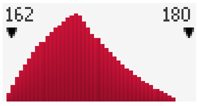
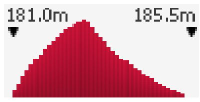
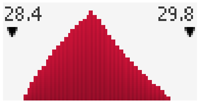
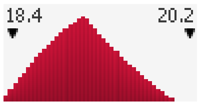
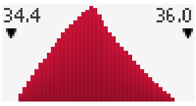
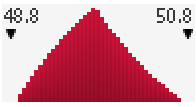
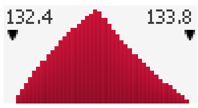
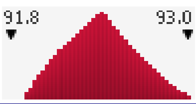
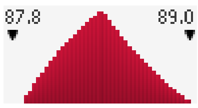
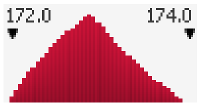
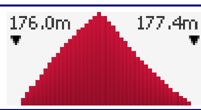
	Name	Graph	Min	Mean	Max
Beans	Ave. Characterization		26.39	26.75	27.23
	Ave. Regeneration		24.31	24.66	25.14
	Ave. Conservation		114.28	114.99	115.95
	Ave. Distribution		58.98	59.34	59.82
Tropical Forages	Ave. Characterization		39.63	46.70	56.25
	Ave. Regeneration		79.40	87.78	99.10
	Ave. Conservation		163.66	176.22	193.20
	Ave. Distribution		162.36	169.12	178.25
Total In Perpetuity for Whole Genebank			181,192,700	182,897,800	185,201,100

Table 9.8. Changes in Average and in perpetuity Costs due to Exchange Rate Fluctuations in 2008, IRRI Genebank

Material	Type of Costs	Graph	Min	Mean	Max
Rice	Ave. Characterization		28.55	29.04	29.62
	Ave. Regeneration		18.41	19.14	20.00
	Ave. Conservation		34.54	35.14	35.85
	Ave. Distribution		48.96	49.75	50.66
Wild Rice	Ave. Characterization		132.48	133.07	133.76
	Ave. Regeneration		91.94	92.42	92.98
	Ave. Conservation		87.92	88.40	88.97
	Ave. Distribution		172.06	172.90	173.88
Total In Perpetuity for Whole Genebank			176,109,800	176,674,400	177,335,800

d) Full costs recovery

As other centers in the CG system CIAT is implementing full cost recovery in their finance systems. Starting 2010 the genebank will be charged per square meter for a number of services provided by CIAT (see Annex 5). Full cost recovery means recovering or funding the full costs of a project or service. The costs directly associated with the project, such as staff and equipment, projects will also draw on the rest of the organization. For example, adequate finance, human resources, management, and IT systems, are also integral components of any project or service. The full cost of any project therefore includes an element of each type of overhead cost, which should be allocated on a comprehensive, robust, and defensible basis. In this sense, each unit within the center should be charged for each costs associated to the projects under their control.

In CIAT the implementation of this system has been scheduled for 2009. Some elements of this system are already in place, i.e. charges for computers, e-mail, internet, and related support. The implementation of this system is expected to increase the costs of genebank operations. Tables 9.9 and 9.10 present the costs of conservation and distribution of genetic materials at the CIAT genebank considering the current charging system and comparing it to the full recovery scheme implemented in 2009[35]. The tables show an increase in average and total in-perpetuity costs for all types of materials, but especially for distribution of accession of tropical forages.[36]

Table 9.9. Comparing Average In-Perpetuity Costs of Conserving and Distributing Existing Accession by the CIAT Genebank (2008)

Crops	No. of acc.	Actual Charges			Assuming Full Costs Recovery		
		Conservation	Distribution	Total	Conservation	Distribution	Total
Cassava	**6,467**	**771**	**934**	**1,705**	**825**	**990**	**1,815**
Operat.		551	771	1,323	605	827	1,433
Beans	**35,903**	**689**	**652**	**1,340**	**588**	**674**	**1,262**
Operat.		641	558	1,199	540	580	1,120
Forages	**23,140**	**956**	**4,195**	**5,151**	**889**	**6,474**	**7,364**
Operat.		849	3,114	3,964	782	5,394	6,176
All crops	**65,510**	**1,955**	**5,057**	**7,011**	**1,795**	**7,373**	**9,168**

Table 9.10. Comparing Total In-Perpetuity Costs of Conserving and Distributing Existing Accession by the CIAT Genebank (2008)

Crops	Actual Charges			Assuming Full Costs Recovery		
	Conservation	Distribution	Total	Conservation	Distribution	Total
Cassava	**2,004,462**	**1,359,683**	**3,364,145**	**2,056,898**	**1,449,709**	**3,506,607**
Operat.	582,584	308,180	890,764	635,021	398,205	1,033,226
Beans	**24,720,186**	**23,402,855**	**48,123,041**	**21,115,327**	**24,195,409**	**45,310,736**
Operat.	22,997,360	20,032,596	43,029,956	19,392,500	20,825,150	40,217,651
Forages	**22,123,207**	**97,065,430**	**131,390,819**	**20,575,856**	**149,818,450**	**181,743,038**
Operat.	30,490,783	72,064,009	102,554,791	28,089,981	124,817,029	152,907,010
All crops	**48,847,855**	**121,827,968**	**182,878,005**	**43,748,081**	**175,463,568**	**230,560,381**

[35] See Annex 6 for a table explaining cost included in the estimation of conservation and distribution costs.
[36] The dramatic increase in costs of conservation and distribution of tropical forages is due to the method used for estimated he costs. With the current charging system costs are allocated based on the number of accession held at the genebank. The use of facilities and services with the full costs recovery scheme is based on area occupied by the genebank.

e) Fund raising

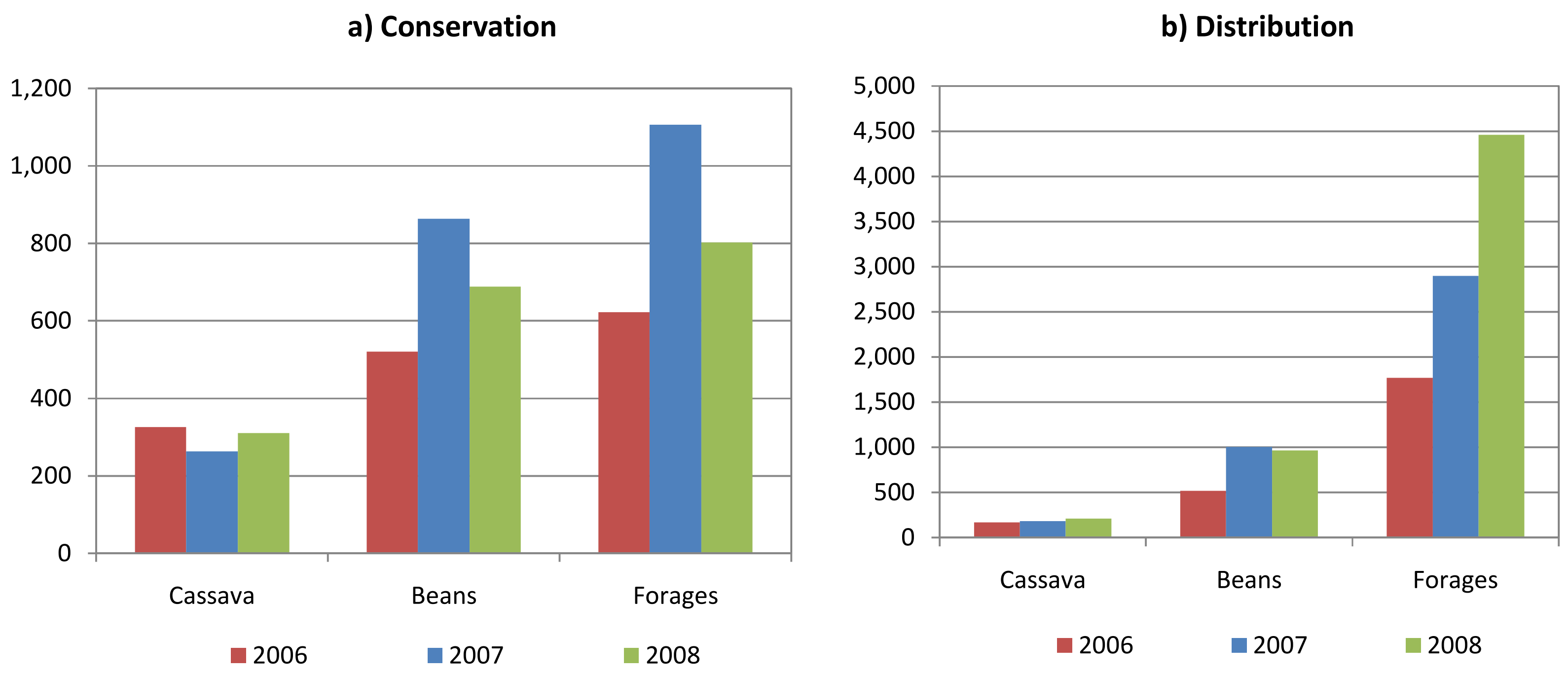
Genebanks need a long term funding scheme in order to guarantee that the genetic material will be preserved not only now in 5 years but also in-perpetuity. The tool has been designed to provide future and in-perpetuity costs of conserving and distributing existing accessions. Table 9.11 is a summary of the conservation and distribution in-perpetuity cost in 2008 for CIAT genebank given the current number of accessions in the genebank. These in-perpetuity costs have been estimated using adding up the average costs of all operations undertaken for the conservation and distribution of an accession.

These estimates are available per year (2006-2008) and show an increasing trend. The variability of average in-perpetuity costs over the three years of information available is shown in Figure 9.1. In the case of conservation the costs tend to increase due to changes in the number of accessions manipulated. In general average costs are lower when more accessions are handled per year (up to a limit). Thus, the average costs of conservation and distribution of all three materials in 2006 are lower than in consecutive years. In the case of distribution of forages the effect is even larger because the number of accessions distributed, regenerated and stored was considerably lower in 2007 and 2008. Thus the specific performance in that year has a great influence on the total estimates. Once again the availability of more years of information would allow for more accurate estimations.

Table 9.11. In-Perpetuity Costs of Conserving and Distributing Existing Accessions in the CIAT genebank in 2008

Crops		No. of acc.	Total cost (US$)		
			Conservation	Distribution	Total
Cassava	**In-vitro + Cryo**	**6,467**	**2,004,462**	**1,359,683**	**3,364,145**
	Noncapital		582,584	308,180	890,764
	Capital		1,421,878	1,051,503	2,473,381
Beans		**35,903**	**24,720,186**	**34,624,429**	**59,344,615**
	Noncapital		22,997,360	31,254,170	54,251,530
	Capital		1,722,826	3,370,259	5,093,085
Forages		**23,140**	**18,438,890**	**103,187,350**	**131,796,316**
	Noncapital		24,774,360	78,185,929	102,960,289
	Capital		3,834,607	25,001,421	28,836,027
All crops		**65,510**	**45,163,538**	**139,171,462**	**1 94,505,076**

a) **Figure 9.1.** Variability in Averages in In-Perpetuity Costs across years and crops, CIAT



SECTION 10

Conclusions and Recommendations

The objective of activity 2.4 was to develop a decision support tool that would help genebank managers and curators make cost-effective decisions. A cost effective genebank is measured in terms of the quantity and quality of the outputs against the expenditures. While developing the tool we have gathered information of 6 genebanks: CIAT, CIMMYT, ICRISAT, IITA, ILRI and IRRI. The genebanks in the CG system share common crops but in most of the cases they have unique world collections. In some cases we have collected costs information for more than one year. For understanding the value of this information it is important to take into account that:

- The operations in the genebank as opposed to the costs estimations do not occur on the annual basis. For instance, at the beginning of the year the genebank does not know what materials on how much of them will be distributed during the rest of the year. A high number of distributed materials during a particular year will affect not only the workload, but will deplete the seed stocks, with a bearing on the work in subsequent years. The seed stocks are depleted not only by distribution but also from the viability monitoring. The intensity of these operations will determine the need for regeneration in the following year.
- The information is collected on an annual basis. This information is very valuable to have an initial idea of the performance of the genebank. It is more difficult to make conclusions on the costs effectiveness of the genebank when it is not possible to make comparisons across years. Note that only for some of the centers (CIAT, IRRI, ICRISAT, and ILRI) we have more than one year of information. With the information currently available is possible to address only some specific management issues like the ones presented in the previous sections (duplication, exchange rate, pre-breeding) that can be affecting the cost-effectiveness of the individual genebank.

- The (reproductive) biology of the species is an important factor to consider. Rice and wheat are among the easiest species to maintain, because they are small seeded, orthodox, and strictly autogamous plants. With a plot of one square meter, you can produce all the seeds that you will need for the distribution, checks on viability, etc, for the 30 years to come. Outbreeder plants like maize or forages are much more complicate and thus expensive to maintain.
- Because the business of the genebank is plant variability the reaction by the plant materials is not always predictable. In other words, you plant one accession in 2010, with the hope to harvest all the seeds in 2012, but that harvest may extend into 2013, even into 2014.
- With the current information and degree of integration of the genebanks it is not possible to compare performance across centers. Factors like location, level of capital inputs, staff qualification, temporary labor cost and qualification, agro-ecological conditions, have a significant impact on the performance of the genebank and thus of their cost-effectiveness. The periodic use of the tool will allow making more in depth analysis.

The information collected also allows us to arrive to the following conclusions and recommendations:

- Characterizations together with regeneration often are resource intensive operations for materials that are propagated by seeds. These two operations tend to demand the highest investment in the genebanks. The costs tend to be higher in centers that managed: 1) large number of accessions like IRRI and CIMMYT in the case of rice and wheat, or 2) a diversity of species like ILRI and IITA.
- Molecular characterization at CIAT as a way to prevent duplication and pre-breeding at CIMMYT as a way to add value to the collection are important impact oriented operations that can be included in future costs evaluations. At ICRISAT molecular characterization adds to the value in identifying genetically diverse trait specific germplasm for use by the crop improvement scientists besides identifying

duplicates. Molecular characterization definitively yields significant savings to the genebank.

- Outsourcing operations might not be a saving strategy for the genebanks. There are several factors to take into account: service provider, types of material, time lags. In general it seems that at least in the case of viability testing, the service provide by the CG genebanks is still the most cost-effective alternative.
- While the current level of information is limited to some centers and only a few years, it seems that the implementation of direct charges might not necessarily have a great impact on the total costs of the genebank. It would have some impact on the operational costs, meaning that the genebanks would need more projects to fund their activities as core money is more restricted. Hence the importance of accounting for actual annual costs rather than averages across years.
- The average costs of some operations are similar across materials. This is expected when activities involved in each operation do not vary significantly across materials (i.e. distribution and seed health testing).
- The main users of the germplasm hold by IITA and ILRI are within the African continent. These genebanks report high distribution costs. Shipping costs within Africa are probably higher than in other latitudes because most shipment is done by courier to avoid long delays in delivery using local postal systems. This is a strong argument to avoid a rationalization and risk strategy that proposes the storing of materials in more central and secured locations (i.e. regional).
- The average costs of distributing materials in some genebanks may seem to be higher than expected. Distribution involves more resources than the inputs used for packing and shipping. Every material distributed requires clearance. Clearance accounts for a large part of the total distribution costs.
- The average costs of seed health testing records does not vary across materials basically due to the formulas used and the way the information was entered to the tool. The total costs have been allocated to the operations based on the number of accessions manipulated. The caveat here is that not all materials within and across

centers require the same health test. This is a point to take into account for future use of the tool and estimation of average costs.

Decision Support Tool

Ideally, the development of the tool should be a dynamic process in which the users' feedback is periodically incorporated to improve the tool. Some recommendations for this future development are:

- A consensus regarding a set of simple, quantifiable performance indicators is central to further progress in developing the tool. In the future the tool must be modified in order to incorporate data that measure performance. An important consideration in the performance is costs versus volume, kind and quality of services. The performance does not refer exclusively to the efficiency of the genebank staff but also to the implementation of efficient practices.
- The tool can be used to produce annual costs reports and a sensitivity analysis based on simulations. These evaluations can be accomplished per genetic material in a specific genebank. The longer term goal, however, is to evaluate genebank performance for the global genebank system. The tool can be used to assemble relevant data, and based on a review of cost studies of provision of public goods; we recommend econometric analysis as a means of evaluating the system.
- The next steps involved in implementing the decision support tool are: a) assemble input use, costs information and feedback from genebank managers, b) add an input sheet for entering performance indicators, c) examine, with genebank managers, how costs can be structurally linked to performance indicators.
- Future applications of the tool can lead to important money savings. For instance, research in seed/ tissue physiology in order to extend the time between each regeneration (seed collection) or sub-culturing (in vitro collection) would lead to significant savings, namely if that time can be doubled, without affecting the viability and the capacity to distribute. The use of the information collected

and simulations based on this information could tell us the magnitude of this savings, and thus how interesting would be the investment in seed/ tissue physiology. Another example of the potential use of the tool is in predicting the performance of DNA bank services. Increasingly, labs around the world ask for germplasm, while they are actually interested in DNA samples. The analysis of costs across centers has shown that germplasm for genetic conservation is expensive to produce because it namely includes at least one health test, and several periodic germination tests. If a recipient is interested in the DNA, that DNA can be produced at the beginning of the conservation cycle, and then stored. Quality DNA could be stored in a freezer at -80C and distributed over 10-15 years (maybe longer, although DNA banks are too recent to provide us with these figures). The cost of that distribution is likely to be lower as compared to regular samples of accessions, because there is no need for viability checking, nor testing for germplasm health.

Next Steps and considerations

In order to make the best use of the outputs of this activity, it is highly recommended that costs information be collected every year using the most current version of the DST. Thus, genebank managers can keep updating the tool and generating a genebank cost database. Preferably the information should be entered at the end of each calendar year and by the same staff member.

The collection of cost information should as well be extended to all centers across the CG system. In this regard ICARDA and CIP are currently collecting this information. ICRISAT is as well collecting information of its genebanks located in Africa. The use of the tool and data entering has been explained to genebank staff in several GPG2 meetings. IITA have been the first genebank in making use of this tool.

The outputs of this activity: 1) an updated and user friendly version of the Decision Support Tool, 2) a Guide to users, and 3) this report will be available to the public in the Knowledge Base web site on this link: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=45&Itemid=142.

A survey to users will as well be posted in the knowledge base web. Ideally the feedback from users should be used to make periodic updates of the tool. The implementation of this activity should be considered in future SGRP projects.

Finally, it is important to mention that IFPRI staff have leas this activity and will be available for providing support to users of the tool and of the other outputs.

References

Altoveros, N. C., and R. V. Rao. 1998. Analysis of information on seed germplasm regeneration practices. In *Regeneration of Seed Crops and their Wild Relatives: Proceedings of a Consultation Meeting, 4-7 December 1995, ICRISAT, Hyderabad, India*, ed. J. M. M. Engels, and R. R. Rao. Rome: IPGRI.

Anon. 1979. Tropical Legumes: Resources for the future. NAS, Washington, DC, USA. 332 pp.

Burstin, J., M. Lefort, M. Mitteau, A. Sontot, and J. Guiard. 1997. Towards the assessment of the costs of genebank management: conservation, regeneration, and characterization. *Plant Varieties and Seeds* 10: 163-172.

Calles, T., M. E. Dulloo, J. M. M. Engels, and I. van den Houwe. 2007. *Best practices for germplasm management: A new approach for achieving genebank standards*. Bioversity International.

Chakrabarty, S.K.; Anitha, K.; Girish, A.G.; Sarath Babu, B.; Prasada Rao, R.D.V.J.; Varaprasad, K.S.; Khetarpal, R.K.; Thakur, R. P. 2005. Germplasm exchange and quaantine of ICRISAT mandate crops. Information Bulleting No. 69. Plant Quarentine Laboratory, ICRISAT, Patancheru.

Day-Rubenstein, K., P. Heisey, R. Shoemaker, J. Sullivan, and G. Frisvold. 2005. *Crop genetic resources: An economic appraisal. A report from the economic research service*. Economic Information Bulletin Number 2. United Stated Department of Agriculture.

De Boer, L. 1992. Economies of scale and input substitution in public libraries. *Journal of Urban Economics* 32 (2): 257-268.

Duke, J. A., B.B. Okigbo and C. F. Reed. 1997. Sphenostylis stenocarpa (Hochst ex A. Rich) Harms. Trop. Grain Leg. Bull. 10:4-6.

Dumet, D.; Ojuderie, O.; Adeyemi, A. 2007a. Cassava in vitro processing and genebanking, IITA Genebank Manual Series.

Dumet, D.; Ojuderie, O.; Adeyemi, A. 2007a. IITA Genebank Manual, Yam in vitro banking, Series.

Dumet, D.; Oyatomi O. 2008a. Seed processing for IITA genebank, IITA genebank manual Series

Dumet D., Adeleke R. and Faloye B. 2008b. Regeneration guidelines: cowpea. In: Dulloo M.E., Thormann I., Jorge M.A. and Hanson J., editors. Crop specific regeneration Guidelines [CDROM]. CGIAR System-wide Genetic Resource Programme, Rome, Italy. 8 pp.

Dumet D. and Ogunsola D. 2008. Regeneration guidelines: yams. In: Dulloo M.E., Thormann I., Jorge M.A. and Hanson J., editors. Crop specific regeneration guidelines [CD-ROM]. CGIAR System-wide Genetic Resource Programme, Rome, Italy. 7 pp.

ECPGR. 2008. A strategic framework for the implementation of a European genebank integrated system (AEGIS). Discussion Paper.European Cooperative Programme for Plant Genetic Resources (ECPGR) .

Engels, J. M. M., and R. R. Rao. 1998. *Regeneration of Seed Crops and their Wild Relatives.* Rome: IPGRI.

Epperson, J. ; Pachico, D.H., Guevara, C. 1997. A costs analysis of maintaining cassava plant genetic resources. Crop Science 37: 1641 - 1649 (1991).

FAO. 2002. International Treaty on Plant Genetic Resources for Food and Agriculture: A global treaty for food security and sustainable agriculture. Food and Agriculture Organization of the United Nations: Rome.

Finch, L., and J. B. Christianson. 1981. Rural hospitals costs: an analysis with policy implications. *Public Health Reports* 96: 423-433.

Fowler, C., and T. Hodgkin. 2004. *Plant genetic resources for food and agriculture: Assessing global availability.* Vol.2004. 29 ed.

Goldsworthy, P. R. (1982). Objectives and achievements in the improvement of grain legumes. *Proceedings of the Nutrition Society,* 41, pp 27-39.

Hanson, J. and R.J. Lazier. 1989. Forage germplasm at the International Livestock Centre for Africa (ILCA): an essential resource for evaluation and selection. Proc. XVI Int. Grass. Congr., Nice, France, pp 265-266.

Hardaker, J. B., R. B. M. Huirne, and J. R. Anderson. 1997. *Coping with risk in agriculture.* Wallingford: CAB International.

Jackson, M. 1997. Conservation of rice genetic resources: The role of the international rice genebank at IRRI. Plant Molecular Biology 35, 61-67.

Johnson, N. ; Pachico, D.; Voysest, O. 2003. The distribution of benefits from public international banks: the case of beans in Latin America. Agricultural Economics 29 (2003) 277 - 286.

Klu, G.Y.P.; Amoatey, H.M.; Bansa, D.; Kumaga, F.K. 2001. Cultivation and use of African yam bean (Sphenostylis stenocarpa) in the Volta region in Ghana. The journal of Food Technology in Africa, Vol. 6, No. 3, 2001. pp. 74-77. On-line search: http://www.bioline.org.br/request?ft01020.

Koo, B., P. G. Pardey, and B. D. Wright. 2003. The economic costs of conserving genetic resources at the CGIAR centres. *Agricultural Economics* 29: 287-297.

Koo, B., P. G. Pardey, and B. D. Wright. 2004. *Saving seeds: The economics of conserving crop genetic resources ex-situ in the future harvest centres of the CGIAR.* Oxfordshire: CABI Publishing.

Koo, B.; Pardey, P.G.; Rao, N.K.; Bramel, P. 2004. ICRISAT Genebank. In: *Saving seeds: The economics of conserving crop genetic resources ex-situ in the future harvest centres of the CGIAR.* Koo, B., P. G. Pardey, and B. D. Wrigh (*edits*). Oxfordshire: CABI Publishing.

Koo, B., P. G. Pardey, P.G.; Jackson, M. 2004. IRRI Genebank. In: *Saving seeds: The economics of conserving crop genetic resources ex-situ in the future harvest centres of the CGIAR.* Koo, B., P. G. Pardey, and B. D. Wrigh (*edits*). Oxfordshire: CABI Publishing.

Koo, B., and B. D. Wright. 2008. The optimal timing of evaluation genebank accessions and the effects of biotechnology. *American Journal of Agricultural Economics* 82 (4): 797-811.

Li, D.; Prtichard, H. 2009. The science and economics of ex-situ plant conservation. Special issue: Plant science research in botanic gardens.

Liu, L. G. 2002. The cost function and scale economies in academic research libraries. *Library Trends* 2002: 406-420.

Madamba, R., Grubben, G.J.H., Asante, I.K. & Akromah, R., 2006. **Vigna unguiculata** (L.) Walp. [Internet] Record from Protabase. Brink, M. & Belay, G. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands. < http://database.prota.org/search.htm>. Accessed 11 January 2010.

Mafla, G.; Roa, J.C.; Aranzales, E.; Debouck, D. G. Handbook of procedures for in-vitro germplasm conservation of the genus Maniot. Genetic Resources - CIAT: Cali. On line source: http://isa.ciat.cgiar.org/urg/urgweb_folder/files/handbookprocedures/en/Microsoft%20Word%20-%20Handbook%20of%20Procedures-In%20vitro.pdf

National Research Council. 2006. The lost crops of Africa, Volume II: Vegetables. The National Academies Press.

Ng , N.Q. 1990. Recent developments in cowpea germplasm collection, conservation, evaluation and research at the genetic resources unit, IITA. In Cowpea Genetic Resources (N.Q. Ng and L.M. Monti, eds.). IITA, Ibadan. Pp 13-28.

Nweke, F. I.; Spencer, D.S.C.; Lynam, J. K. 2002. The cassava transformation: Africa's best kept secret. Michigan State University Press: East Lansing.

Pardey, P. G., B. Koo, M. E. Van Dusen, B. Skovmand, and S. Taba. 2001. Costing the Conservation of Genetic Resources: CIMMYT's Ex Situ Maize and Wheat Collection. *Crop Science* 41: 1286-1299.

Pardey, P. G., B. Koo, M. E. Van Dusen, B. Skovmand, S. Taba, B. Wright. 2004. CYMMYT genebank. In: *Saving seeds: The economics of conserving crop genetic resources ex-situ in the future harvest centres of the CGIAR.*Koo, B.; Pardey, P.; Wright, B.D. (*edits.*). Oxfordshire: CABI Publishing.

Porter, D. 1992. Economic botany of Sphenostylis (Leguminosae). Econ. Bot. 46(3): 262-275.

Rao, N. K., J. Hanson, M. E. Dulloo, K. Ghosh, D. Nowell, and M. Larinde. 2006. *Manual of seed handling in genebanks.* Handbook for Genebanks No. 8, Maccarese, Italy: Bioversity International.

Salcedo, J; Debouck, D.G; Torres, A.M; Guevara, C. 2006. Flow Chart of Operations for Bean and Tropical Forage Germplasm. Genetic Resources - CIAT: Cali.

SGRP. 2009. Mapping our future: Sustaining the CGIAR Centres' Genbanks for greater impact. Second Draft.

Smale, M., and A. G. Drucker. 2007. Agricultural Development and the Diversity of Crop and Livestock Genetic Resources: A Review of the Economics Literature. In Biodiversity Economics, ed. A. Kontoleon, U. Pascual, and T. Swanson. Cambridge: Cambridge University Press.

Smale, M., and B. Koo. 2003. *Genetic Resources Policies: What is a Gene Bank Worth?* IFPRI: Washington, D.C.: IFPRI, IPGRI, and the Systemwide Genetic Resources Program.

Taba, S., D. van Ginkel, D. Hoisington, and D. Poland. 2004. *Wellhausen-Anderson Plant Genetic Resources Center: Operations Manual.* El Batan, Mexico: CMMYT.

Upadhyaya, H.D., Bramel, P.J. and Sube Singh. 2001. Development of a chickpea core subset using geographic distribution and quantitative traits. Crop Science 41: 206-210.

Upadhayaya, H.D; Gowda, C.L.L., Sastry, D.V.S.S.R. 2008. Plant genetic resources management: collection, characterization, conservation and utilization. SAT eJournal (ejournal.icrisat.org) An Open Source Journal published by ICRISAT: December 2006, Volume 6.

Virchow, D. 2003. Current expenditures on crop genetic resources activities. In *Efficient conservation of crop genetic diversity*, ed. D. Virchow. Berlin: Springer-Verlag.

Virchow, D. 1999. *Spending on conservation of plant genetic resources for food and agriculture: How much and How efficient?* ZEF Discussion Papers on Development Policy. Bonn: Center for Development Research.

ANNEXES

Annex 1
Identifying Performance Indicators

Performance concept	Measurable Proxy	Units	Comments
Genetic Integrity	Genetic drift during regeneration[37]	Probability that an accession retains, in the offspring following regeneration, all alleles of one gene present in the parental generation at a frequency of greater than 5%	• Not appropriate or feasible as a routine annual performance indicator. • Measures of loss of genetic integrity are best measured over one cycle of regeneration.
	Probability of contamination with wrong seed	Probability that an accession contains, in the offspring following regeneration, <0.01% seed originating from a different accession, plot or population	• Not appropriate or feasible as a routine performance indicator. Not feasible because it requires very costly analyses and a multi-year research project to assess. Not appropriate because it depends on protocols adopted, which don't change from year to year. Therefore use this indicator for (a) initial assessment of genebank quality or (b) evaluating the consequences of a proposed change in protocols, but not (c) for annual assessment of progress.
	Probability of contamination with wrong pollen	Probability that an accession contains, in the offspring following regeneration, <0.01% pollen originating from a different accession, plot or population	• Not appropriate or feasible as a routine performance indicator, as above
	Number of labeling errors	Probability that the label on the packets of harvested offspring	• Not appropriate or feasible as a routine performance indicator, as above

[37] *A priori*, we can mathematically calculate a figure for drift, but this figure will depend on protocols adopted, which don't change from year to year. *A posteriori*, we can estimate an actual change (although it is not simple to separate drift from other causes of change), but this requires costly analyses and a multi-year research project; plus the average result will, like the *a priori* estimate, depend on the protocols adopted, which don't change from year to year. Therefore the use of this indicator is appropriate for (a) initial assessment of genebank quality and (b) evaluating the consequences of a proposed change in protocols; but it is not for annual assessment of progress. The *a priori* calculation is a cheaper and better guide than *a posteriori* estimation.

Performance concept	Measurable Proxy	Units	Comments
		seed of an accession placed in the genebank match the label on the parental seed packet	
	Number of accessions lost per unit of time	Number lost, as percentage of the number in the genebank at the start of the review period (1 year)	
	Genetic drift during storage		
Security	Backlog of safety duplication (1) in primary backup location	$\left(\frac{N_T}{N_C}\right)\left(1+\frac{N_R}{N_S}\right)-\frac{\overline{T}(N_C-N_T)}{N_C}$ NT=Total number of accessions in safety backup; NC=Total number of accessions in collection; NR=number of accessions backed up during review period; NS=number of accessions not yet backed up at the start of the review period; $\overline{T}$ = average number of years accessions not yet deposited have been waiting to be deposited (number of years waiting = the lesser of (a) years since the backup agreement was established and (b) years since the accession was acquired). Set NR/NS = 0 if NS =0.	• On one hand, the number or % in safety backup is a compound of only one aspect of total performance to date. It does not measure current performance or all aspects of performance (e.g. for values less than 100% backup. It doesn't take into account how long the remaining accessions have been waiting to be deposited). On the other hand, the number of accessions backed up during the current review period or that number as % of the number not previously backed up, because when approaching 100% back up, this becomes unstable and it wrongly indicates poor performance during years when new germplasm is acquired but not backed up in the same year - not poor performance. Not just how long remaining accessions have been waiting to be backed up, because that also becomes unstable near 100% backup – 1 accession waiting 20 years is not bad. So an indicator proposed by R. Sackville-Hamilton combines of all three and that seems to show good behavior. It tends to 1 for complete safety backup, <1 for incomplete backup, increasing with current progress to maximum 2 in year of completing backup, and decreasing to <0 with increasing average number of years waiting.
	Backlog of safety duplication (2) In	Same equation as above	• Since the opening of the Global Arctic Seed Vault at Svalbard, safety duplication should now be divided into

Performance concept	Measurable Proxy	Units	Comments
	Svalbard		two – safety backup at primary location and safety backup at secondary location (Svalbard)
	Time between regeneration cycles	Average number of years since the accessions regenerated during the review period were previously regenerated	• Not a good proxy because. The longest potential time is a genetic feature, variable between accessions. We cannot set reasonable targets without knowing the longest potential time.
Longevity	Quantity of high viability seeds per accession	Average of [(weight (g) of seed per accession in bulk storage in active collection) * (most recent estimate of % germination rate of each of those samples)]	
Availability	Number of accessions with known longevity		• Mostly unknown because it requires long time to estimate this value.

Source: Brainstorming activity with Genebank managers (R. Sackville-Hamilton, J. Hanson, D. Debouck, I. Sanchez, H. Upadhyaya)

Annex 2
Number of accessions of tropical forages and years installed in field and greenhouses in CIAT, 2008

Years	Palmira	Quilichao	Popayan	Greenhouses	Total
< 1 año	714	704		533	1951
1	220	705	7	293	1225
2	78	150	40	137	405
3	50	123	7	247	427
4	13	29	11	35	88
5	19	26	20	34	99
6	12	6	9	21	48
7	4	7	3	12	26
8	10		1	2	13
9	24	6	2	4	36
10	33	23	11	16	83
11	1	9	2	7	19
12		14		2	16
13	4	8		7	19
14	2	16			18
15	10	32		7	49
16	18	35		3	56
17		1		1	2
18		9			9
19	2	8			10
20	1	1	2		4
21	10	4		4	18
22	6	13	623	2	644
23		2			2
Total	**1231**	**1931**	**738**	**1367**	**5267**

Source: Ciprian, A. (personal communication)

Annex 3:
Characters used to form the chickpea core collection at the Patancheru genebank, ICRISAT. Mean and range of variation for some quantitative traits in the chickpea collection at ICRISAT

Character Trait	No. Acc.	Mean	Min	Max
Days to 50% flowering	16 928	62.4	31.0	107.0
Days to maturity	16 928	115.9	84.0	169.0
Flowering duration	11 208	33.6	13.0	75.0
Plant height (cm)	16 840	37.5	14.0	96.3
Plant height (cm)	16 840	37.5	14.0	96.3
Plant width (cm)	16 775	40.5	13.3	124.0
Apical primary branches	16 928	1.4	0.0	12.0
Basal primary branches	16 928	2.7	0.3	15.7
Basal secondary branches	16 928	3.1	0.0	13.7
Tertiary branches	16 928	4.6	0.0	28.2
Pods per plant	16 879	40.5	3.0	251.0
Seeds per pod	16 882	1.2	1.0	3.2
100-seed weight (g)	16 928	16.8	3.8	65.4
Protein content (%)	12 973	19.5	8.0	29.6
Seed yield (kg ha^{-1})	16 356	1216.3	70.0	5130

Source: Upadhyaya, H.D., Bramel, P.J. and Sube Singh. 2001. Development of a chickpea core subset using geographic distribution and quantitative traits. Crop Science 41: 206-210.

Annex 4.
Fluctuation of exchange rate in Colombia 2007-09

Source: Grupo Bancolombia

Annex 5
CIAT Genetic Resources Unit – Direct Charges - 2009

GENETIC RESOURCES UNIT

COST PER SQM - 2009					
Area	Total Sqm (M^2)	Electricity / Water	Other Services	$ Total Cost	Total per Sqm (M^2)
Office	299	$10,412	$14,782	$25,195	$84
Laboratory	242	$17,364	$26,349	$43,713	$180
Warehouse	145	$75	$1,785	$1,859	$13
Area de Servicio	44	$1,201	$2,076	$3,277	$75
Areas de trabajo	228	$308	$4,321	$4,629	$20
Cuarto frio	352	$10,514	$27,487	$38,001	$108
Cuarto con control de H y C	85	$11,405	$9,550	$20,955	$247
Greenhouses	846	$9,277	$22,926	$32,202	$38
Casas de mallas	1,342	$169	$17,141	$17,311	$13
	3,583	60,723	126,418	187,141	

USE OF PUBLIC AREA - 2009		
Cost per employee	# of Employees	Total Cost
942	51	48,037

DEPRECIATION & INSURANCE COST (other equipment/Furniture) - 2009
$42,487

IT COST - 2009			
IT Equipment	Amount	Cost per unit	Total Cost
Desktop (core)	23	$3,500	$80,500
Laptop (core)	1	$4,100	$4,100
			84,600

TOTAL DIRECT COST	$362,265

Annex 6
Estimation of Conservation and Distribution Costs

Annex 6.1 Example for clonal materials

Activity		Annual Costs (US$/acc)	In Perpetuity (US$/acc)	Capital (US$/acc)
Conservation				
General management		0.69	23.55	13.19
New introduction				
	Initial multiplication			
	Molecular characterization			14.54
	Seed health testing			8.71
	In vitro multiplication and storage	7.14	157.54	19.14
	Information			0.61
	Initial duplication			5.70
Information		0.77	26.36	42.00
Safety duplication		13.95	276.24	112.85
Cryopreservation		44.22	44.34	3.12
Seed health testing		23.32	23.32	
Total Cost		**90.09**	**551.35**	**219.87**
Distribution				
General management		0.69	23.55	13.19
Molecular characterization				14.54
Seed health testing		23.32	23.32	8.71
Information		0.77	26.36	42.00
In-vitro conservation		7.14	157.54	19.14
Distribution		15.74	540.43	65.01
Total Cost		**47.65**	**771.19**	**162.60**

Annex 6.2. Example for seed propagated materials

Activity		Annual Costs (US$/acc)	In Perpetuity (US$/acc)	Capital (US$/acc)
Conservation				
General management		0.69	23.55	3.23
New introduction				
	Acquisition			0.00
	Seed health testing			2.90
	Initial multiplication			5.37
	Characterization			2.85
	Information			0.03
	Initial viability testing			1.20
	Initial duplication			0.05
Safety duplication		0.85	1.44	0.09
Long-term storage		14.37	493.50	5.83
Information		1.13	38.69	0.92
Viability testing		2.24	16.29	15.03
Regeneration		12.33	48.18	10.50
Seed health testing		18.89	18.89	
Total Cost		**50.49**	**640.54**	**47.99**
Distribution				
General management		0.69	23.55	3.23
Characterization				2.85
Viability Testing		2.24	14.05	1.20
Seed Health Testing		18.89		2.90
Information		1.13	38.69	0.92
Corto Plazo		4.06	139.31	53.90
Regeneration (25 yrs.) (c)		12.33	114.49	11.74
Distribution		6.64	227.88	17.15
Total Cost		**45.96**	**557.96**	**93.87**