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Efficient Conservation Of Crop Genetic Diversity

Theoretical Approaches And Empirical Studies

with 6 Figures and 76 Tables

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8 Costs of Conservation of Agrobiodiversity in India

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Introduction

Plant germplasm is a nonrenewable natural resource indispensable for the sustenance of human life on this earth. The story of human civilization is actually also a story of plant domestication and gender role differentiation. It is said that only after domestication did the role of women start to become more and more differentiated. Women have played the most pivotal role in the selection, storage and in situ conservation of landraces. It is important to appreciate that studies on the cost of conservation also capture, in that sense, the hidden and unappreciated contribution women have made in this gigantic task. In this contribution we will not be able to deal with this issue in detail, because we are focusing essentially on the components contributing to the cost of ex situ conservation.

Biological diversity is used to describe the 'number, variety and variability of living organisms within each variety or species in a given ecosystem (Heywood and Baste, 1995). CBD and UNEP (1992) have defined this as the variability among living organisms from all sources, including, inter alia, terrestrial, marine and aquatic ecosystems as well as the ecological complexes of which they are a part. Biological diversity is usually considered at three different levels: genetic, species and ecosystem diversity. Genetic diversity refers to the variety of genetic information contained in all of the individual plants, animals and microorganisms. Genetic diversity occurs within and between populations of species and between species. Species diversity refers to the variety of living species. Ecosystem diversity relates to the variety of habitats, biotic communities and ecological processes, as well as the tremendous diversity present within ecosystems in terms of habitat differences and the variety of ecological processes (Commonwealth of Australia, 1993).

Agricultural biological diversity, in short, agrobiodiversity, refers to the variability among living organisms associated with the cultivation of crops and rearing of animals along with the ecological complexes of which they are a part (Convention on Biological Diversity, 1992). Agrobiodiversity focuses on that part of biodiversity that has undergone selection and modification over millennia by human civilization to better serve human needs (Wood, 1993). It has also been defined broadly as *"the part of biodiversity which nurtures people and is nurtured by people"* (FAO, 1995). The human cultures that have emerged and adapted to the local environment, discovering, using, and altering local biological resources over the course of time, have all contributed to its evolution. It is the interplay among human cultures and their biological diversity that helps in articulating social preferences for different attributes of biodiversity. This is how agrobiodiversity evolves as a direct consequence of social, cultural and institutional conditions at a given place.

The domestication of wild biodiversity was necessitated by the emerging social structures requiring a stable supply of food and other biological materials. The emergence of agrobiodiversity in the regions where wild relatives abound was also a consequence of gender roles and socio-economic conditions.

Importance of Biodiversity

Biodiversity provides a foundation for ecologically sustainable development and food security. There are four kinds of values for any given environmental resources: option value, use value, exchange value and existence value. The unknown potential of genes, species and ecosystems is of inestimable, but certainly high, value. The ecosystems rich in biodiversity possess greater resilience and are therefore able to recover more readily from biotic and abiotic stresses, such as drought, environmental degradation, pests, diseases, epidemics, etc. Hence, a decline in biological diversity puts the functioning of ecosystems at risk.

The cultural value of biological diversity conservation for present and future generations is another important reason for conserving it today. Human cultures coevolve with their environment, and the conservation of biological diversity can be important. Human cultures are shaped in part by the living environment that they in turn influence, and this linkage has profoundly helped to determine cultural values. The natural environment provides for many of the inspirational, aesthetic and educational needs of people of all cultures, now and in the future. Intangible values, such as the deep spiritual, social, protective and recreational significance of biodiversity, are difficult to identify at this stage, however.

Agrobiodiversity has been slowly and naturally evolving since the beginning of life. Human existence (and that of most other organisms) is heavily dependent on primary producers, i.e., plants. Food security and self-sufficiency, particularly in the marginal areas, depend on the availability of crop genetic diversity. The adaptive complex of crop genetic diversity enables farmers to adopt crops suited to their ecological niches and cultural food production systems and practices. This wider environmental adaptability of diverse crops and varieties enables the farmers to use them as risk adjustment measures. Therefore, the availability of agrobiodiversity enables farmers to attain food security in varied ecological regions by reducing their vulnerability to shocks or fluctuations in crop production. The challenge is to assess (i) the amount of diversity farmers still maintain, (ii) the economic costs and (iii) the perceived environmental considerations.

The plant breeders and biotechnologists have the immense task of developing new crop varieties to overcome problems caused by pests, diseases and abiotic stresses. They are also confronted with newer challenges concerning sustainable agriculture, environment protection and satisfaction of the increasing demand for food, fodder, fiber and fuel. In the search for desirable genes in different crop species, the plant breeders and biotechnologists depend upon the crop diversity as an immediate resource to tailor the new varieties and hybrids or for reconstructing the existing genotypes in accordance with the requirements of time and space. Crop diversity contributes to the stability and sustainability of farming systems and is valued for providing important attributes, including, inter alia, agronomic characteristics, biotic and abiotic stresses and other factors of cultural and socio-economic importance. In addition, crop diversity serves as a direct or indirect source of several products, such as medicines, life-saving drugs, vitamins, minerals, various industrial products, etc. Crop diversity also provides an insurance against unknown future needs as well as conditions, as these are likely to hold still undiscovered cures for known and emerging diseases and is a fortune that can be tapped as human needs change.

Apart from the above uses, the crop genetic resources may also act as the indicator of the ecosystem's health. HILL and RAMSAY (1977) demonstrated the use of various weeds as indicators of soil mineral properties. Likewise, certain varieties are suitable for very precise conditions of onset, duration and cessation of floods in humid and sub-humid areas. If in certain lowland micro-environments the height of the water stand changes because of siltation, the farmer may change specific landraces for that location. In fact, GUPTA (1995) has argued that by mapping local varieties one can also map the variability in the micro-environment because of the high correlation between the two.

Human activities also shape biodiversity. In the past, when the earth's natural abundance seemed boundless, there was little concern for the effects of human activities on the world's stocks of biological diversity. However, recently, because of the extent of the natural destruction caused to the environment by human interferences, the importance of biological diversity has regained attention.

Threats to Biodiversity

Even in prehistoric times, humans had a considerable impact upon biodiversity. Many large animals and forest systems have been exploited to extinction. Man's impact (per time unit) was low in early times. It has gradually increased with growing technology, population, production and consumption rates in modern times. Biodiversity is currently decreasing at an unprecedented rate (see, i.e., The Global Biodiversity Assessment, 1995). The enormous genetic diversity is being lost mainly due to genetic erosion, genetic vulnerability and genetic wipe-out. These processes are not mutually exclusive, but are, in fact, operating together, driven by the demand of an increasing population and rising expectations.

Developmental pressures on the land resources, deforestation, changes in land use patterns and natural disasters are contributing to abundant habitat fragmentation and destruction of the crops and their wild relatives. Social disruptions or wars also pose a constant threat of genetic wipe-out of such promising diversity (OECD, 1996). Overexploitation and also the introduction of invasive alien species are the other factors contributing to the loss of genetic resources. More recently, global warming and a high degree of pollution have also been recognized as further causes for the loss of biodiversity (Myers, 1994).

Over the millennia, traditional farmers have given us an invaluable heritage of thousands of locally adapted genotypes of major and minor crops that have evolved because of natural and artificial selection forces. The quest for increasing food production and the ensuing success achieved in several crops have replaced the land races by uniform, true-breeding cultivars or special hybrids of controlled parentage. This heritage is threatened because of recent developments, and, consequently, the ancient patterns of variation are being obliterated (WCMC, 1992). The factors contributing to the erosion of agrobiodiversity are: (a) the increasing technological and financial support for high-yield varieties that will replace local varieties, (b) the large scale modification of the medium upland farming conditions that may lead to faster diffusion of high-yielding varieties, (c) the high partitioning efficiency that gives a comparative advantage to high-yielding varieties that can often perform better even in conditions where the local soil nutrition is below average and (d) the market preferences of consumers for uniform grains, vegetables or foods.

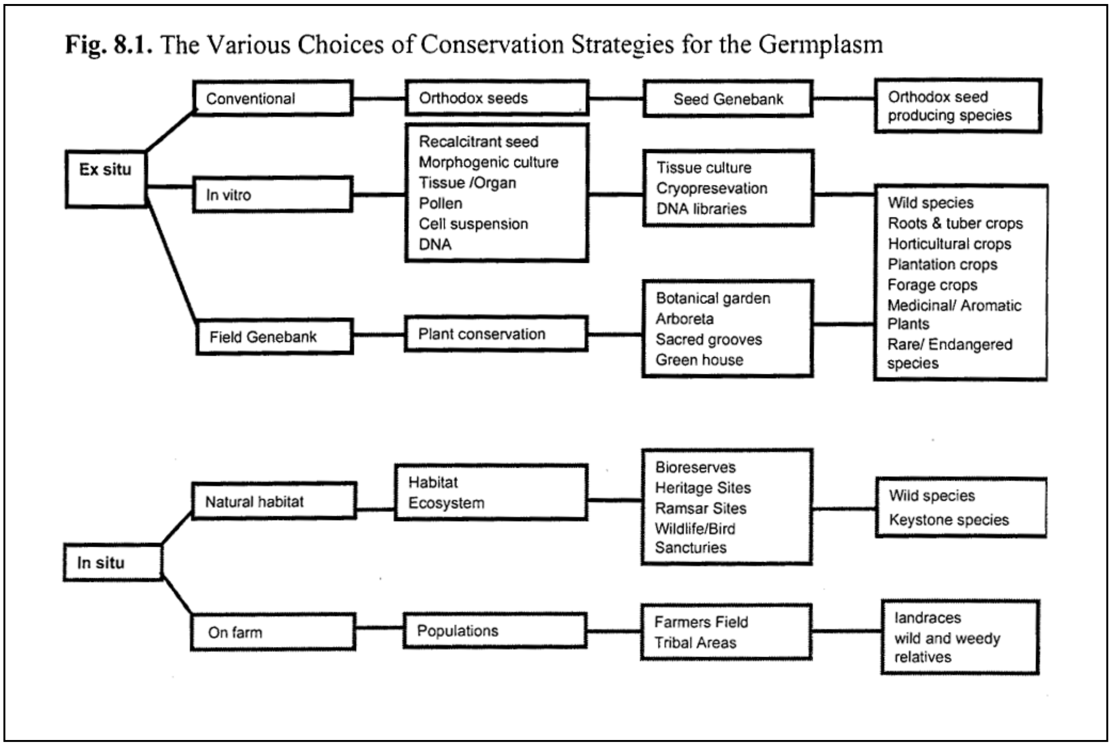
A study has shown that between 1989 and 2001 there was a decline of about 16% to 100% (i.e., total extinction) in the area under indigenous varieties of various crops in three villages in flood-prone parts of eastern India. The decline was maximum in rice (about 85-100%) and minimum in chick peas (16-65%), maximum in the plots of the medium-high land type and belonging to small farmers compared to marginal or large farmers (Gupta et al., unpublished). Without remedial action, genetic erosion will inevitably increase, and the costs of replacement of diversity needed in the future by the community will be much greater. These costs can be reduced by strategic and timely conservation actions (Commonwealth of Australia, 1993).

The decline of agrobiodiversity has made the food system extremely vulnerable. The possibilities of insects, pests or disease spreading over vast areas have increased because of genetic uniformity. Agrobiodiversity therefore contributes directly to the containment of such risks.

This loss in diversity is taking place at a time and speed when new tools of biological research enable scientists to focus as much on the diversity of genes as on the diversity of genotypes. Future progress in the improvement of crops largely depends on immediate conservation of genetic resources for their effective and sustainable utilization. To date, India retains an extensive reservoir of ancient diversity in farmer's fields in many parts of the subcontinent, but especially in mountainous, drought- or flood-prone and tribal areas in which the inherent physical, ecological or sociological barriers have impeded adoption of modern technologies.

In view of the above, the developing programs on biodiversity conservation and on their sustainable use in food and agriculture have been major concerns both at the national and international levels. Since most species are interdependent for their survival, conservation strategies have to take into account all elements of biodiversity.

Fig. 8.1. The Various Choices of Conservation Strategies for the Germplasm



Conservation Strategies

The choice of a conservation strategy depends mainly on the nature of the material to be conserved, i.e., the life cycle, mode of reproduction, size and ecological status (OCED, 1999). Two major approaches for crop diversity conservation are: (i) in situ and (ii) ex situ (see Fig. 8.1).

In Situ Conservation

In situ conservation means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties (UNEP, 1992; UNEP 1995). The Convention on Biological Diversity has given highest priority to this approach of conservation, which includes species protected in the wild as well as landraces, i.e., cultivars adapted to the local climate, soil and pests as well as to the taste of local people (Primack, 1993), and other cultivated forms maintained by farmers. This also includes the preservation of indigenous knowledge (social, cultural and religious status), agro-ecosystems and other wild cultivars (CBD, 1992).

In situ conservation enables the preservation of evolutionary processes that generate new germplasm under conditions of natural selection and the maintenance of important field laboratories for crop biology and biogeography. It also serves as a continuous source of germplasm for ex situ conservation. Further, for those countries that have abundant crop germplasm resources, it provides an important option for conservation with a wider participation.

Four basic kinds of multidisciplinary research are required to successfully run the in situ conservation (FAO, 1996a):

1. ethno-botanical and socio-economic research to understand and analyze farm ers' knowledge, selection and breeding as well as utilization and management of crop genetic resources with the approval of the involved farmers with applicable requirements for the protection of their knowledge and technologies;
2. population and conservation biology to understand the dynamics of the local landraces and farmer's varieties (population differences, gene flow, degree of inbreeding, selection pressure, etc.);
3. crop improvement research in mass selection and simple breeding without significant losses in local biodiversity;
4. extension studies for less-known crops, including their seed production, marketing and distribution.

The criteria for site selection for in situ conservation within the study areas are:

1. a wide range of diversity of a single or a few crop species within a given site,
2. the ecological heterogeneity,
3. the possibility to control or monitor the site and
4. easy access for monitoring and management (Tan and Tan, 1998).

However, the germplasm maintained by in situ conservation is highly vulnerable to the threat posed by (a) genetic drift, (b) inbreeding, (c) habitat loss, (d) competition with exotic species and (e) pest infestation. Beside these factors, the inability to readily provide crop germplasm to the breeders is the major limiting factor of this approach in contrast to ex situ conservation.

Ex Situ Conservation

Ex situ conservation refers to the conservation of germplasm away from its natural habitat. This complementary approach for conservation began on a wide scale about three decades ago and is now practiced, to some extent, in almost all countries as a means to conserve crop species diversity for posterity. This strategy is particularly important for crop gene pools and can be achieved by propagating and maintaining the plants in genetic resource centers, botanical gardens, tissue culture repositories or in seed genebanks (OCED, 1999).

Notwithstanding the advantages of ex situ conservation, there are limitations to relying only on this approach:

- Many important species are underrepresented because of the recalcitrant nature of the seeds.
- Genetic shifts or alterations cannot be ruled out because of inappropriate storage conditions.
- Since the crops are grown with the external application of fertilizers and pesticides and the use of heavy machinery, the plants slowly get accustomed to more congenial conditions; the root architecture and assimilatory properties get modified since nutrients and porous, well-plowed soil are available.
- Ex situ conservation does not maintain the evolutionary processes that created the crop germplasm. The genetic resources are not exposed to natural or artificial pressure, and, therefore, no chance exists for further evolution or adaptations.

Various approaches are employed for the ex situ conservation depending upon the mode of reproduction and nature of plants to be conserved. Seed genebanks deal with the conservation of seeds with "orthodox seed" behavior (which can withstand drying below a certain moisture level). Apart from seed genebanks, in vitro repositories or cryobanks are also widely employed for the conservation of germplasm when either the seeds are unable to withstand drying below a certain moisture level, i.e., "recalcitrant seeds", or seeds are not produced at all, i.e., vegetatively propagated plants (OECD, 1999). The details of these strategies are discussed later in the text.

Need to Calculate the Costs of Conservation

During the past one and a half decades, with the increase in the activities of conservation, the costs involved in such activities have been debated. Various studies for estimating the costs of conservation have been carried out, adopting different methodologies (Jarret and Florkowski, 1990; Epperson et al., 1997; Pardey et al., 1998 and 1999). The costs of conservation are highly crop and location specific (Virchow, 1999). Therefore, it is imperative to calculate them for estimating the capital required for conserving the germplasm in the given region. Such studies also draw attention to the critical components of efficient conservation and could also guide future conservation strategies and the formulation of cost-effective approaches. The estimation of the costs of conservation helps the international communities to allocate the appropriate financial assistance to the country for conserving its natural resources.

The conservation of agrobiodiversity contributes to food security by providing sources of such genes as might hold clues for increasing production in the future or for providing specific biochemicals used in drugs or other such products. It is well recognized that productivity of landraces is generally lower than the high-yield varieties. Therefore, whenever a new high-yield variety becomes available, the pressure for the extinction of the existing landraces becomes higher. The study of the cost of conservation helps us to appreciate the requirement of resources for conserving agrobiodiversity, which on its own may not be carried out by the farmers without external incentives. The estimation of the costs of the study of conservation also helps with the allocation of scarce resources among competing crops that need to be covered under the conservation programs.

The overall costs of conservation are broadly made up of fiscal and monetary costs and opportunity costs. The fiscal costs represent the costs that have to be budgeted and invested either on the national or international levels for the planning, implementing and running of ex situ and in situ conservation activities. These costs are determined by specific conservation activities, depreciation costs for investments and the costs for institutional and political regulation for the access to germplasm. Additionally, the costs for compensation and incentives paid for maintaining the collected germplasm are also included. The opportunity costs, on the other hand, reflect the foregone benefit for the country by maintaining the diversity of genetic resources in the field (Bretting and Duvick, 1997).

Methodology

In the present study an attempt has been made to give a brief account of the cost components involved in the various activities listed in Figure 8.2 for efficient ex situ conservation. These activities have been drafted following discussions with the cross section of scientists and administrators engaged in the activities of conservation and management of germplasm in India. The authors would like to acknowledge Dr P.L. Gautam, Director of the National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India, for his valuable suggestions and guidance in finalizing the various components involved in the conservation of germplasm and contributing to the costs. Further, the relevant information and suggestions provided by Dr Anuradha Agrawal and Ms J. Radhamani as well as other scientists of NBPGR are also duly acknowledged.

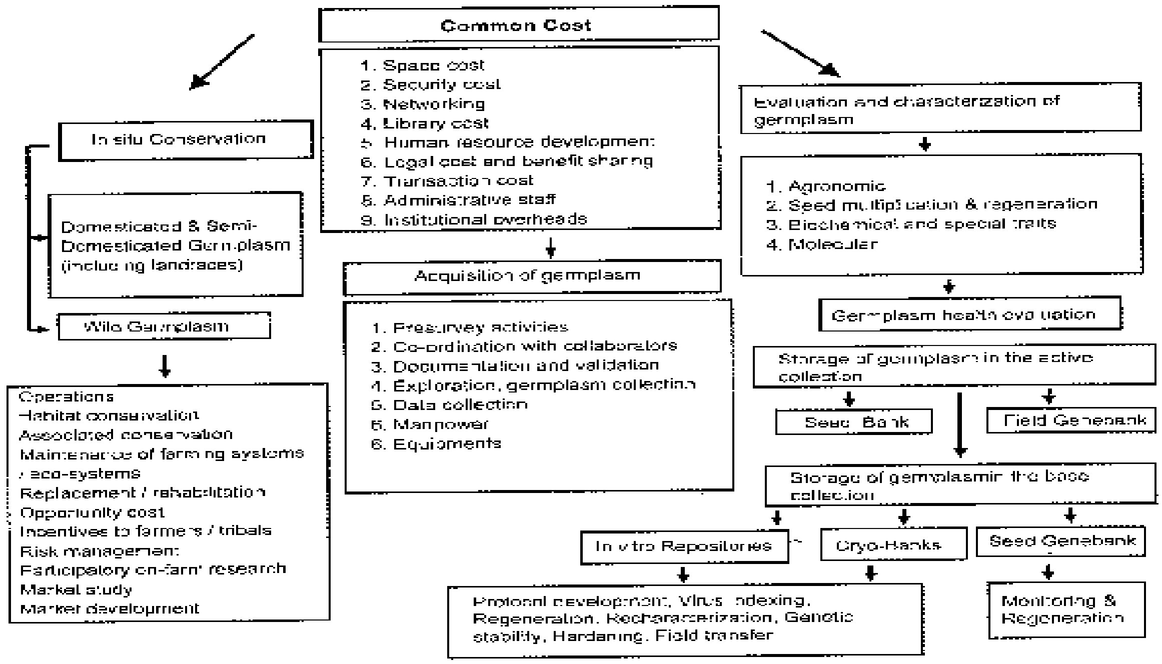
Test Crops

The components of costs involved in conservation have been discussed in the present study by taking the examples of five crops: paddy, sorghum, cowpea, banana and tea. The rationale behind selecting these five crops is the differential modes of reproduction and the storage techniques.

Paddy

India has abundant resources of wild species of paddy, particularly *Oryza nivara, O. officinalis* and *O. granulata.* The wild species of paddy can be found in many different natural habitats, from shade to full sunlight, and can be either annual or perennial in nature. Some wild species occur as weeds in and around paddy fields and even hybridize naturally with the cultivated forms.

Fig. 8.2. A Schematic Representation of the Various Components Attributing to the Cost in the Conservation of the Germplasm



This complex association between cultivated and wild forms can enhance the diversity of paddy crops in traditional agriculture systems, where farmers often grow mixtures of varieties, to provide a buffer against the risk of complete loss of the crop as a result of biotic and abiotic stresses (Sharma et al., 1988; Jackson et al., 1997). According to an estimate, about 50,000 landraces of paddy are thought to exist in India. The full spectrum of paddy germplasm thus includes:

- wild *Oryza* species and related genera,
- natural hybrids between the cultigens and wild relatives and primitive cultivars of the cultigens in areas of paddy diversity,
- germplasm generated in the breeding programs, including pure lines or inbred selections of farmers' varieties, Fl hybrids and elite varieties of hybrid origin, breeding materials, mutants, polyploids, aneuploids, intergeneric and inter specific hybrids, etc. and
- commercial types, obsolete varieties, minor varieties and special purpose types in the centers of cultivation.

The exploration and collection activities for indigenous paddy cultivars were initiated around the turn of the century. However, the systematic explorations were initiated only during 1955-1960 by the Jeypore Botanical Survey in South Orissa and adjoining areas of Madhya Pradesh. Since then, numerous explorations have been carried out resulting in acquisition of nearly 66,745 accessions from the various parts of the country (Singh et al., 2000).

Sorghum

Sorghum is believed to have originated from wild species in western, eastern and eastern-Central Africa. India is considered to be one of the centers of diversity for sorghum. About 30,000 accessions of sorghum are believed to exist in India. Besides India, also Ethiopia, Indonesia, Myanmar and the Philippines are first choice areas when it comes to the collection of diversity of sorghum (Stenhouse et al., 1997).

Cowpea

The cowpea is an ancient crop and has been domesticated since the Neolithic period throughout the world. The African gene center, especially Ethiopia, is considered as the primary center of diversity for the cowpea, whereas Southeast Asia, mainly India and China are considered as the secondary centers of origin. Five subspecies of *Vigna unguiculata,* i.e., *dekindtiana, sesquipedalis, unguiculata, cylindrica* and *mensensis,* have played an important role in the evolution of the cultivated type (Ng and Singh, 1997).

In India, the cowpea is widely distributed from the foothills of the Himalayas to the southern peninsula. The species is endowed with diversity in two forms: *V. unguiculata* var. *unguiculata* and *V. unguiculata* var. *biflora.* The occurrence of *V. unguiculata* var. *sesquipedalis* is sporadic. According to estimates, about 3,000 accessions of cowpea are available in India (Ng and Singh 1997).

Tea

The cultivated population of tea has been categorized into three types on the basis of their morphological, anatomical and biochemical characteristics. These are the (i) Assam type *(Camellia assamica),* (ii) China type (C. *sinensis)* and (iii) Cambod type (C. *assamica* ssp. *lasiocalyx).* The Yunnan provenance of South-West China is considered to be the center of origin for the genus *Camellia.* However, Northeast India, bordering Burma, harbors maximum diversity and wild relatives of C. *assamica* (Singh, 1988).

The germplasm of tea in India has been collected from Northeast India, Burma, China, Kampuchea, Sri Lanka, Vietnam and the USA. The collection of the germplasm of tea was initiated in 1823. About 3,000 accessions of tea are assumed to exist in the Indian center. The germplasm of tea is lost at an enormous rate due to the uprooting of old stocks and replacement of these with a few selected ones (Singh, 1988).

Banana

Southeast Asia and the Malayan archipelago are the centers of origin for *Musa*. The Indian gene center, extending to Southeast Asia, is believed to be one of the centers of origin and diversity for the edible banana *(Musa acuminata, M. balbisiana)*. Several species, such as *M. acuminata, M. balbisiana,* their interspecifc hybrids along with wild types, occur in India (Harry et al., 1997).

The probable areas for exploration in India are Assam, the northeastern hills, the Western Ghats, Chotannagpur, Orissa and Kerala. More than 300 landraces of banana and plantain are found in diverse habitats throughout India (Iyer and Subramanian, 1988).

Procedures Adopted

The cost figures involved in the different conservation activities for these crops have been calculated as: Cost (US $/accession/year) = cost figure (in Rs.) x 1 /conversion factor x I/no, of accession, based on collected per year.

The cost figures involved in the various activities were initially calculated in Indian Rupees (Rs.), which were subsequently converted to US dollars, employing a conversion factor of 44. The number of accessions collected per year varies with the crop species, as it depends on the extent of genetic diversity within the species. In addition to this, the cost figures in the tables (Tables 8.1-8.6) have also been expressed, when distributed over the duration of the activity (as discussed later in the text).

The manpower required for each activity has been allocated at three levels: (a) the scientist (at Rs. 2,50,000 per year), (b) the research associate (at Rs. 1,25,000 per year) and (c) the technical person (at Rs. 1,25,000 per year), along with the semi-skilled help on a contractual basis as per the requirement of the activity. To account for the depreciation and replacement costs, the total expense required for the equipment in a particular activity has been distributed over a period of 5 years to get the per year costs.

The Common Costs

There are certain prerequisites for initiating any type of conservation activity. In the present study they have been grouped under common costs, which refer to the sum total costs involved in the establishment of basic infrastructure, human resource development, salaries of the engaged staff members as well as for other administrative activities, including institutional overhead charges, etc.

The space costs have been computed, including the land and construction costs for the farms and buildings, which are imperative for a proper infrastructure. Once the establishment of the basic infrastructure has taken place, it is expected to serve for a long period of time, so these costs have been distributed over a period of 50 years. The germplasm conservation activities can effectively be carried out by involving various stakeholders. Thus, the setting up of an efficient network and communications facilities is an important activity that will contribute substantially to the common cost. Keeping in view the rapid advancement in information technology, these facilities would require regular replacement and upgrading. Thus, these costs have been distributed over a period of five years. The security of the collections is of prime importance, and the institutions involved would have to make annual expenditures for this activity.

To organize any collection mission and develop an appropriate conservation strategy, it is essential to acquire adequate information about the nature of the crop (mode of reproduction, flowering season, ethno-botanical information, etc.), areas harboring the diversity and details about the region to be explored (topography, climatic conditions, traditions, culture, etc.) (Clay, 1991; Fingleton, 1993; Martin, 1995). This information is usually gathered through libraries, the Internet as well as by coordinating with the concerned institutes. It is essential to establish a library in the institute, which would require financial resources for the subscription prices of the journals, costs of the books, establishment and maintenance of the suitable database, salaries to the concerned staff members as well as for other miscellaneous expenses. The establishment of infrastructure for these facilities has been assumed to be a part of the space cost. However, annual maintenance charges towards library costs have been taken into account.

It is essential to keep the staff members engaged in the conservation activities abreast of the latest developments in their field. To achieve this, various training programs would have to be organized periodically in the advanced centers within the nation and, in certain cases, in other countries. In organizing such programs, expenditures are mainly incurred by traveling, the daily allowances of the trainees as well as the experts and also, in respect to bench fees, transportation, stationary, consumables, etc. Usually, a suitable honorarium is given to the invited experts for their services. The total expenses allocated for organizing such training programs have been calculated on the yearly basis.

In the changing global scenario where the implementation of IPR-related issues could gain tremendous importance, a provision towards legal costs has been provided for carrying out activities like the filing of patents, checking for piracy, benefit sharing, etc., every year.

The proper utilization of the germplasm collected can only be ensured if it is made available to the interested persons. Expenses incurred would be for different activities associated with the transactions involving germplasm (handling, requests for acquisition and dissemination of the material). In addition, the expenditure for developing material transfer agreements for transactions involving germplasm from field genebanks (for local communities), active sites (national and local) and base collection (national and international) would have been accounted for in the transaction costs.

In the present study, the expenditure in regard to the technical manpower required for the various components of conservation has been accounted for in the respective activity. However, as the administrative staff engaged in the maintenance of the accounts and for record keeping would assist in all the components,

Table 8.1. Common Costs Involved in the Conservation of Germplasm

Common costs	Details	Rs. '000	USD '000	USD / accession / year
Space costs	Building (50 years) and land farm costs	150,000	3,409	0.341
Security costs	For buildings, farms and genebanks at locations	200	4.54	0.023
Networking	Data entry and information management consumables	500	11.36	0.057
	Equipment vast, initial networking costs (5 years	1,000	22.73	0.0023
	Manpower: 1 scientist, 2 technical persons, contractual labor	1,000	22.73	0.114
	Miscellaneous (including maintenance contracts for equipment)	1,500	34.09	0.171
Library costs	Books, journals, etc..	1.500	34.09	0.171
H. R. D.	National trainings	1,500	34.09	0.171
	International trainings	500	11.36	0.057
Legal costs and benefit sharing	For checking piracy, filling and and challenging patents Manpower: 1 manager, 1 technical person	500	11.36	0.057
Transaction costs	Handling costs Request of material, acquisition and dissemination costs, costs of developing Material Transfer Agreements (MTA)	200	4.54	0.023
Administrative staff	Accounts maintenance and records upkeep	1,500	34.09	0.171
Subtotal		159,900	3,634.000	1.358
Institutional overheads	10% of the annual common costs	15,990	363.398	0.136
Total		**175,890**	**3,997.38**	**1.494**

The composition of the cost may vary with the magnitude of the conservation activities undertaken as well as with the site of conservation, but components attributing to the total cost would remain the same. Initially, the acquisition costs will be higher with low maintenance costs, while in subsequent years, the maintenance costs would be higher (at the end of 10 years). Although the acquisition cost will be zero, this will act as a replacement cost in case of any calamities/natural disasters (5% of the total costs).A provision of 10% of the total annual costs has been included as an institutional overhead for expenditure towards the annual maintenance and depreciation. In the present study, while calculating the total common costs, the cost figures have been distributed for 200,000 accessions, assuming it to be the total diversity of the five test crops to be collected and conserved as active or base collections (see Table 8.1).

Costs for Acquisition of Germplasm

The germplasm is mainly collected from the regions harboring the maximum diversity of the crop. During the exploration, emphasis is laid on the collection of local landraces along with their wild relatives. Broadly, two kinds of exploration are planned based on (a) the priority of crops, i.e., crop specific, and (b) the area/region surveyed, i.e., region specific. However, in cases of severe threats due to natural calamities (cyclones, droughts, floods, etc.) and other forms of human interference (building up of dams, infrastructure development, etc.), mission-oriented explorations are also undertaken to conserve the germplasm diversity of the specific regions in an urgent, time-bound manner. The costs incurred for the crop-specific explorations are generally expected to be more •than those required for region-specific explorations, while the costs involved in the mission explorations are still higher. The duration of the exploration trip as well as the number of accessions collected per trip will depend upon the germplasm to be collected. The exploration trips focusing on the collection of the germplasm of crops with "orthodox seed" behavior are generally of longer duration compared to those aimed for the collection of "recalcitrant" crops or "vegetatively propagated" crop species. The germplasm of the latter categories is perishable in nature, remaining viable for a very short time, and needs to be processed and transported to the conservation site rapidly. Thus, a smaller number of accessions for recalcitrant and vegetatively propagated crops can be collected per trip compared to the orthodox seed-producing crops.

Passport data information regarding the habitat, nature of the plant, its growth behavior, socio-economic values, ethno-botanical information, etc., is recorded at the time of the collection of the germplasm. This information generally accompanies the germplasm to the genebank, where it is entered in the database for its analysis. The information not only facilitates in setting up the priorities for conservation (Nabhan, 1996), but is also helpful in monitoring the changes in the diversity of the crop through time and, consequently, in estimating the risks of its genetic wipe-out (Brush, 1991; Belon, 1996). The generation of the standard formats for the passport data sheets requires thorough discussions with experts. The expenditure in this activity is attributed to organizing meetings, to discussions and to imparting adequate training to the explorers to record such information.

Women have a profound knowledge of plants and their environment. Traditionally, women have been using a variety of indigenous plants, trees and animals, and they have a direct stake in the preservation. Studies have revealed that women have greater interest in preserving and conserving crop plants, forests and other natural resources for perpetual use. Men, on the other hand, are more often concerned with converting these resources into cash. In addition, women are traditional caretakers of genetic and species diversity in agriculture. Their knowledge of the necessary growing conditions and nutritional characteristics of various species gives them a crucial fund of experiences in seed selection and plant breeding. This enables them to maintain the genetic diversity required to adapt to intermittent changing parameters and to ensure the survival of these traditional crops adapted to local conditions and tastes. It is therefore important to collect the gender-based knowledge of the locals about a crop, as this plays an important role in agrobiodiversity conservation and management, especially in the era of increasing adoption of monoculture (Krishna, 1998). However, it is being realized, through participatory breeding programs as well as work on local knowledge, that domestication of different species is also accompanied by the development of cultural institutions. Which kinds of grains and pods or parts of plants are used in various rituals or food recipes are to some extent shaped by the socio-cultural tradition in a given community. Sometimes the importance of a genuine germplasm cannot be appreciated without looking at the associated knowledge system and social life in the place where it occurs. The interaction between ecosystem variability and genetic variability also needs to be studied carefully for designing conservation programs. The variability in the topography, soil textures and structures, micro environmental conditions and existing ecological communities shape or define the range within which biological evolution may take place. However, the pressure of social preferences modifies the bioevolutionary pressure by shaping the choice of characteristics in the agrobiodiversity in the given context.

The team for carrying out an exploration mission would include the plant explorer, crop researcher and extension worker along with the local guide. Usually, at the collection site, the help of contractual laborers is also required. The exploration team needs to be equipped with the important accessories (such as exploration kits, cameras, GPS, computers/data loggers, vasculum, etc.) required during the tour along with a proper means of transportation. For organizing such trips, the components attributing to the costs are the expenditures to fulfill the basic requirement and the equipment needed for the purpose along with the traveling and other allowances given to the team members. Sometimes, to collect primitive and rare cultivars, incentives are also given to the farmers or the locals for collecting the germplasm as they maintain it in their fields along with the other prevalent varieties.

At the base campsite the collected accessions are properly processed (dehusking, threshing, etc.), cleaned, and packed in the appropriate containers, using the help of contractual laborers. Subsequently, they are transported to the genebank. The labor costs and the miscellaneous expenditures incurred in the transportation of the collected germplasm to the genebank from the site of collection contribute to the variable costs.

Table 8.2. Estimated Costs Involved in the Acquisition of Germplasm of Paddy, Sorghum and Cowpea

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year [d]
Paddy				
Pre-survey activities [a]	500	11.36	2.272	0.046
Documentation and validation [b]	100	2.27	0.454	0.009
Processing [c]	1,000	22.73	4.544	0.092
Travel expenses	1,000	22.73	4.544	0.092
Equipment	500	11.36	2.272	0.046
Manpower	1,700	38.64	7.768	0.155
Contingency	500	11.36	2.272	0.046
Total	5,300	120.45	24.126	0.486
Sorghum				
Pre-survey activities [a]	400	9.09	3.028	0.061
Documentation and validation [b]	100	2.27	0.757	0.015
Processing [c]	700	15.91	5.299	6.106
Travel expenses	600	13.64	4.542	0.091
Equipment	400	9.09	3.028	0.061
Manpower	1,500	34.09	11.363	0.227
Contingency	400	9.09	3.028	0.061
Total	4,100	93.18	31.045	0.622
Cowpea				
Pre-survey activities [a]	100	2.27	7.567	0.153
Documentation and validation [b]	50	1.14	3.783	0.077
Processing [c]	150	3.41	11.367	0.230
Travel expenses	160	3.64	12.131	0.242
Equipment	100	2.27	7.567	0.153
Manpower	300	6.82	22.734	0.460
Contingency	100	2.27	7.567	0.153
Total	960	21.82	72.716	1.468

[a] Co-ordination with prospective collaborator(s), developing formats, miscellaneous. Library, review, communication / Internet time (to be met from common costs).

[b] Physical, social, religious, culinary characters.

[c] Exploration, germplasm and passport data collection; processing of material (cleaning, drying, etc.) collection/active; collection, documentation, consumables.

[d] Distributed over a period of 50 years.

The costs of augmentation of the germplasm of the test crops are mainly attributed through various activities, such as pre-survey activities, coordination with the collaborators, developing formats for recording the passport data information as well as the expenditures incurred during the organization of exploration trips, including the processing cost and the manpower required for these activities.

The acquisition cost of paddy has been calculated assuming that 50,000 samples are to be collected. Experience shows that in exploration trips of 15-20 days, about 250 accessions can be collected, thus requiring 20 explorations per year to collect 50,000 accessions in 10 years (at 5,000 accessions per year) with an expenditure of Rs. 40,000 per exploration. Since the activity of exploration is season specific, it has to be done in collaboration with other scientists; hence, a provision of 2 human years for fulfilling this requirement has been assumed. Once collected and sent for long-term conservation, the accession does not need to be collected again). In view of tropical conditions in the gene-rich and resource-poor countries, the costs of collection of the accession have been distributed over 50 years. The total expenditure on the acquisition of a single accession of paddy amounts to US $ 0.486 per year (see Table 8.2).

The acquisition cost of sorghum has been calculated assuming that 30,000 samples are to be collected. Experience shows that in an exploration trip of 15-20 days, about 200 accessions can be collected, thus requiring 15 explorations per year to collect the entire germplasm in 10 years (at 3,000 accessions per year) with the expenditure of Rs. 40,000 per exploration. Once collected, the accession is frozen and does not need to be collected again. The costs of collection of a single accession have been estimated to be US $ 0.622 per year, when distributed over 50 years (see Table 8.2).

The acquisition costs of cowpea have been calculated assuming that 3,000 samples are to be collected. Experience shows that in an exploration trip of 15-20 days, about 75 accessions can be collected, thus requiring four explorations per year to collect all the diversity in 10 years (at 300 accessions per year) with the expenditure of Rs. 40,000 per exploration. The total costs of acquisition when distributed over 50 years have been estimated to be US $ 1.468 per accession per year (see Table 8.2).

The germplasm of tea is collected through seeds, which are perishable and have to be processed within 10 days. Because of the shorter duration of the exploration trips, a sum of Rs. 20,000 has been allocated per trip in the present case. However, few additional trips are required prior to the collection of the germplasm for the marking and selection of elite trees. Experience shows that in an exploration trip of 7-10 days, about 30 accessions can be collected, thus requiring 100 explorations in 10 years (at 300 accessions per year). Once collected, the accession is frozen through the technique of cryopreservation and does not need to be collected again. The costs in this case have been distributed over 50 years and are estimated to be US $ 2.983 per accession per year (see Table 8.3).

Table 8.3. Estimated Costs Involved in the Acquisition of Germplasm of Tea and Banana

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year [d]
Tea				
Pre-survey activities [a]	200	4.54	15.12	0.306
Documentation and validation [b]	50	1.14	3.783	0.077
Processing [c]	200	4.54	15.12	0.306
Travel expenses	500	11.36	37.867	0.767
Equipment	100	2.27	7.567	0.153
Manpower	400	9.09	30.300	0.607
Contingency	500	11.36	37.867	0.767
Total	1,950	44.30	147.62	2.983
Banana				
Pre-survey activities [a]	100	2.27	75.667	3.027
Documentation and validation [b]	50	1.14	37.633	1.514
Processing [c]	200	4.54	151.234	6.054
Travel expenses	40	0.91	30.330	1.213
Equipment	50	1.14	37.633	1.514
Manpower	250	5.68	189.330	7.573
Contingency	100	2.27	75.667	3.027
Total	790	17.95	597.49	23.922

[a] Co-ordination with prospective collaborator(s), developing formats, miscellaneous. Library, review, communication / Internet time (to be met from common costs).
[b] Physical, social, religious, culinary characters.
[c] Exploration, germplasm and passport data collection; processing of material (cleaning, drying, etc.) collection/active; collection, documentation, consumables.
[d] Distributed over a period of 50 years for Tea and 25 years for banana.

The acquisition costs of banana have been calculated assuming that 300 samples are to be collected. The collection trips for banana are of short duration, as the vegetative propagules are perishable in nature. The total expenditure incurred per exploration trip has been assumed to be Rs. 20,000. Experience shows that in an exploration trip of 7-10 days about 15 accessions can be collected, thus requiring an average of two explorations per year to collect the entire diversity in 10 years (at 30 accessions per year). The vegetative propagules collected for banana are conserved employing the technique of tissue culture. In the tissue culture repositories, a high risk of loss exists. It is assumed that the same accession would need to be collected again; therefore, the cost of the collection of banana is US $ 23.922, when distributed over 25 years (see Table 8.3).

Costs for Management of Active Collections

The value of collected and conserved germplasm can only be realized after proper characterization and evaluation, complemented by biosystematic studies of the wild species. The responsibility for evaluation, supply for utilization and maintenance of the germplasm for the medium-term are entrusted with the "active sites," and the collections are called "active collections".

The germplasm at the active sites is used for agronomic, biochemical, special traits, gender-based knowledge and molecular evaluations as well as for regeneration.

Evaluation of the Germplasm

Evaluation and characterization of genetic resources are of prime importance in making a large collection available for wide use. The past experiences have amply demonstrated how enormous diversity of crops has been utilized in solving the current food problems. The evaluation of germplasm collected in the past has resulted in identification and has contributed significantly to the crop improvement programs owing to their various agronomic, genetic and biochemical traits. Evaluation of genetic resources involves the recording of morphological, physiological, genetic and biochemical traits. Besides these, the need for evaluation for the authenticity of the gender-based knowledge collected from the locals (while acquiring germplasm) has been felt recently.

The germplasm is raised in the fields for agronomic evaluations. The cost components attributing to this activity would include the costs of land as well as of farm equipment (tractor, row-disk bedder, seed spreader, harvester, etc.), which contribute to the fixed costs. The manpower required for various farm practices as well as inputs, such as pesticides, insecticide, fertilizers, etc., are the components of the variable costs. Once the crop is established in the field, various agronomic traits (plant height, branching pattern, leaf size, vigor, flora features, etc.) listed in the plant descriptors are recorded. The generation of such descriptors requires thorough discussions with the crop curators for whom various meetings, seminars as well as discussion fora are organized. The organization of all this as well as the training imparted to the concerned people to record the details accurately contributes further to the costs. The recording of these details would also require equipment (leaf area meter, balances, seed counters, etc.), miscellaneous items and manpower that add up to further costs. The number of plants that can be raised in a unit area also contributes to significant differences in the cost component, which depends on the growth pattern of the crop, e.g., in a given area a larger number of plants of paddy can be raised than of banana. The total cost required for the agronomic evaluations for all the crops when calculated per accession is least for paddy compared to the other crops, as the number of accessions are more for the former (see Table 8.4 and Table 8.5).

Table 8.4. Estimated Costs Involved for the Evaluation and Characterization of Germplasm of Paddy, Sorghum, Cowpea

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year [d]
Paddy Agronomic evaluation etc. [a]	500	11.36	2.27	0.227
Manpower Contingency	1,500	34.09	6.82	0.682
Equipment (farm and	500	11.36	2.27	0.227
laboratory)	250	5.68	1.14	0.114
Total	2,750	62.49	12.5	1.25
Biochemical and special traits evaluation [b]	1.500	34.09	6.82	0.682
Equipment	1,000	22.73	4.55	0.455
Manpower	700	15.91	3.18	0.318
Contingency	1,000	22.73	4.55	0.455
Total Molecular evaluation [c]	4,200	95.45	19.1 113.63	1.91 2.27
Sorghum				
Agronomic evaluation etc. [a]	300	6.82	2.27	0.227
Manpower Contingency	1,250	28.41	9.470	0.947
Equipment (farm and	400	9.09	3.03	0.303
laboratory)	200	4.55	1.52	0.152
Total Biochemical and special traits evaluation [b]	2,150	48.87	16.29	1.629
	1,000	22.73	7.58	0.758
Equipment	700	15.91	5.30	0.530
Manpower	500	11.36	3.78	0.378
Contingency	500	11.36	3.78	0.378
Total Molecular evaluation [c]	2,700	61.36	20.44 113.63	2.044 2.27
Cowpea				
Agronomic evaluation etc. [a]	150	3.41	11.37	1.137
Manpower Contingency	150	3.41	11.37	1.137
Equipment (farm and	100	2.27	7.57	0.757
laboratory)	100	2.27	7.57	0.757
Total	500	11.36	37.88	3.788

Table 8.4. (cont.)

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year[d]
Biochemical and special traits evaluation [b]	500	11.36	37.87	3.787
Equipment	300	6.82	22.73	2.273
Manpower	150	3.41	11.37	1.137
Contingency	200	4.55	15.17	1.517
Total	1,150	26.14	87.14	8.714
Molecular evaluation [c]			113.63	2.27

[a] Seed multiplication/ regeneration; characterization (based on known descriptors), consumables.
[b] Preparation of samples, consumables, chemicals, and glassware.
[c] Genetic diversity, genetic purity, stability at Rs. 5000 per sample.
[d] Distributed over a period of 10 years for agronomic, biochemical and special traits evaluation and 50 years for molecular evaluation.

Detailed evaluation would require the evaluation of biochemical parameters as well as some special traits (palatability, fodder value, nutritional aspects, etc.). The biochemical evaluation requires setting up the laboratory with various kinds of sophisticated equipment (spectrophotometer, balances, lyophilizer, centrifuges, etc.) to increase the efficiency and authenticity of the results and to carry out any other associated supportive research. The costs thereby incurred contribute to the fixed costs, whereas the variable costs for a biochemical laboratory include the expenditure for chemicals, glassware and manpower.

The need for the evaluation of molecular characteristics, their genetic homogeneity as well as stability during storage, is also felt, and it is being used routinely at many sites of conservation. The molecular evaluation of the germplasm is a sumptuous exercise as it requires very sophisticated equipment (spectrophotometer, flourimeter, PCR, electrophoretic apparatus, etc.) and expensive chemicals, though the basic set up of the laboratory and its requirements are similar to that of a biochemistry laboratory. Although the cost for developing protocols for different crops would vary, the cost of molecular evaluation has been assumed to be Rs. 5,000 per accession, irrespective of the crop.

The costs for agronomic, biochemical and special traits evaluations for paddy, sorghum, cowpea and tea are distributed over a period of 10 years, as these would be repeated with each regeneration cycle. However, for the molecular traits, these would be evaluated only once; therefore, the cost is distributed over a period of 50 years. The crops maintained in vitro have to be established in the field after about 10 cycles of sub-culturing. Assuming that the sub-culturing concerning banana is to be done after one year, the cost involved in the evaluation activities has been distributed over a period of 10 years. Since the chances of alteration in molecular traits is very high in in-vitro cultures in banana the molecular evaluations have been calculated for each regeneration cycle, i.e., every 10 years (see Table 8.4 and Table 8.5).

Table 8.5 Estimated Costs Involved for the Evaluation and Characterization of Germplasm (for Tea and Banana)

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year[d]
Tea				
Agronomic evaluation etc. [a]	200	4.55	15.17	1.517
Manpower	400	9.09	30.30	3.030
Contingency	100	2.27	7.57	0.757
Equipment (farm and laboratory)	100	2.27	7.57	0.757
Total	800	18.18	60.61	6.061
Biochemical and special traits evaluation [b]	500	11.36	37.87	3.787
Equipment	300	6.82	22.73	2.273
Manpower	200	4.55	15.17	1.517
Contingency	_ 200_	4.55	15.17	1.517
Total	1200	27.28	90.94	9.094
Molecular evaluation [c]			113.63	2.27
Banana				
Agronomic evaluation etc. [a]	50	1.14	38	3.8
Manpower	250	5.68	189.33	18.933
Contingency	300	6.82	227.33	22.733
Equipment (farm and laboratory)	50	1.14	38	3.800
Total	650	14.78	492.66	49.266
Biochemical and special traits evaluation [b]	100	2.27	75.67	7.567
Equipment	50	1.14	38	3.800
Manpower	100	2.27	75.67	7.567
Contingency	100	2.27	75.67	7.567
Total	350	6.95	265.01	26.501
Molecular evaluation [c]			113.63	11.36

[a] Seed multiplication/ regeneration; characterization (based on known descriptors), consumables.
[b] Preparation of samples, consumables, chemicals, and glassware.
[c] Genetic diversity, genetic purity, stability at Rs. 5000 per sample.
[d] Distributed over a period of 10 years for agronomic, biochemical and special traits evaluation and 50 years for molecular evaluation in tea and 10 years in banana.

Regeneration of Germplasm

The germplasm is regenerated to maintain the safety duplicates as well as to increase availability of seed quantity of the germplasm maintained in the "active sites" when the percentage germination falls below 85%. To regenerate the germplasm in the fields, the routine agricultural practices are followed by a proper crop-specific strategy to maintain the genetic integrity of the accession. The regeneration cost depends on the reproductive behavior of the crops, as the regeneration cost for cross-pollinated crops is more than that for the self-pollinated ones, as the former requires elaborate arrangements and manpower for manual pollinations to maintain the genetic integrity of the original collection (Breese. 1989; Porceddu and Jenkins, 1991).

The costs of land as well as of farm equipment (tractor, row-disk bedder, seed spreader, harvester, etc.) contribute to the fixed costs, while the manpower required for various farm practices as well as the agrochemicals (such as pesticides, insecticide, fertilizers, etc.) are the components of the variable costs. These costs for regeneration would be similar to those for seed multiplication. However, these have not been separately accounted, assuming that the fresh collections will not need regeneration.

Germplasm Health Evaluation

The crop plants and the pests attacking them have evolved together through a long and continuous association. Before sending the germplasm to the genebank, it is imperative to evaluate the health of the seeds for effective and safe conservation. To make sure that the collected germplasm is free from contaminants, it is subjected to different types of examinations. The generalized tests required for the detection of superficial contaminants make use of common laboratory instruments and chemicals. However, the specialized tests required for the detection of the hidden infestations necessitate sophisticated instruments and diagnostic kits (Ram Nath, 1993). In some cases, where the infestation is detected in the seeds, the valuable germplasm is salvaged employing various techniques, e.g., chemotherapy, thermotherapy, mechanical cleaning or meristem tips culture. The salvaged germplasm is subsequently raised in isolation in the glasshouse.

Common laboratory equipment, the specialized instruments and the establishment of glasshouse facilities contribute to the fixed cost component. The glassware, the chemicals and the manpower contribute to the variable costs. The health of the germplasm is to be evaluated once before sending the germplasm to the genebank. Therefore, in this case the total cost is distributed over a period of 50 years (see Table 8.6).

Table 8.6. Costs Involved in the Health Evaluation of Germplasm of Paddy, Sorghum, - Cowpea, Tea and Banana

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year[b]
Paddy				
Consumables	500	11.36	2.27	0.046
Equipment	1,000	22.72	4.54	0.092
Manpower	1,500	34.09	6.82	0.136
Contingency	200	4.55	0.91	0.018
Miscellaneous [a]	300	6.82	1.36	0.027
Total	3,500	79.54	15.9	0.319
Sorghum				
Consumables	300	6.82	2.272	0.046
Equipment	700	15.91	5.30	0.160
Manpower	750	17.05	5.68	0.113
Contingency	200	4.55	1.517	0.031
Miscellaneous [a]	100	2.27	0.757	0.015
Total	2,050	46.6	15.526	0.310
Cowpea				
Consumables	200	4.55	15.167	0.306
Equipment	400	9.09	30.30	0.607
Manpower	150	3.41	11.36	0.230
Contingency	100	2.27	7.567	0.153
Miscellaneous [a]	100	2.27	7.567	0.153
Total	950	21.59	71.961	1.444
Tea				
Consumables	200	4.55	15.167	0.306
Equipment	300	6.82	22.72	0.460
Manpower	200	4.55	15.167	0.306
Contingency	100	2.27	7.567	0.153
Miscellaneous [a]	100	2.27	7.567	0.153
Total	900	20.46	68.188	1.374
Banana				
Consumables	300	6.82	227.33	22.733
Equipment	800	18.18	606.00	60.600
Manpower	250	5.68	189.33	18.933
Contingency	300	6.82	227.33	22.733
Miscellaneous [a]	200	4.55	151.23	15.123
Total	1,850	42.05	1,401.22	140.12

[a] Including maintenance contracts for equipment.
[b] Distributed over a period of 10 years for banana and 50 years for other crops.

Banana requires thorough indexing for viruses and other microbes, as these multiply rapidly under cultural conditions, and their presence poses a great threat to efficient conservation, since the costs involved in this activity are higher. Moreover, this activity needs to be carried out every 10 years, as the accessions conserved through in vitro techniques are transferred to the fields after ten cycles of sub-culturing (approximately one cycle/year). Therefore, the total cost involved in the evaluation of health has been distributed over a period of 10 years in the case of banana in contrast to other crops (see Table 8.6).

Maintenance of Active Collections

The active collection sites for crops with "orthodox seed" behavior are medium-term storage modules, while those for the "recalcitrant" or "vegetatively" propagated plants are the field genebanks.

Medium-Term Storage

The active collections for paddy, sorghum and cowpea are effectively stored in the medium-term storage modules, maintained at a temperature of 4°C and 35% RH[51]. After proper drying, the seeds are stored in various types of containers, such as cloth bags, metal cans or glass jars, and kept in the storage racks of the modules. The establishment of an infrastructure would include the storage module, having components such as insulating panels, a cooling system, a dehumidifier, electrical panels, etc. Since the facilities are to be operated at full efficiency and any break down would result in spoilage of the germplasm, it is essential to have built-in redundancy of important components in the system. Similarly, to circumvent the ill effects of power failure, an efficient backup supply needs to be ensured.

In addition to the modules, associated equipment for seed processing, seed drying, sealing, documentation, etc., is required. The consumables (baskets, containers, etc.), manpower and running costs of the module including the energy costs along with the maintenance costs for the equipment contribute to the variable cost component. Once kept in the medium-term module, the accession can maintain its viability of 10-15 years; hence, the total cost incurred for the storage of germplasm in the active collections can be distributed over the period of 10 years (see Table 8.7).

[51] RH: Relative humidity.

Table 8.7. Estimated Costs Involved in the Storage of Germplasm in the Active Collection (Seed Genebank)

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession	USD / accession / year[c]
Processing cost Consumables	1,000	22.73	4.545	0.455
Equipment	750	17.05	3.409	0.341
Manpower	700	15.91	3.18	0.318
Miscellaneous [a]	500	11.36	2.272	0.227
Contingency [b]	1,000	22.73	4.545	0.455
Total	3,950	89.78	17.951	1.796
Sorghum				
Processing cost consumables	800	18.18	6.06	0.606
Equipment	500	11.36	3.78	0.378
Manpower	500	11.36	3.78	0.378
Miscellaneous [a]	500	11.36	3.78	0.378
Contingency [b]	500	11.36	3.78	0.378
Total	2,800	63.62	21.18	2.118
Cowpea				
Processing cost consumables	150	3.41	11.36	1.136
Equipment	300	6.82	22.72	2.272
Manpower	150	3.41	11.36	1.136
Miscellaneous [a]	100	2.27	7.567	0.757
Contingency [b]	100	2.27	7.567	0.757
Total	800	18.18	60.574	6.058

[a] Including maintenance contracts for equipment.
[b] Including energy charges and emergency backup power supplies.
[c] Distributed over a period of 10 years.

Field Genebank

The active collection sites for the vegetatively propagated plants such as banana as well as for the recalcitrant crops such as tea are the field genebanks. Germplasm maintained in the field genebanks fall in two categories. Type I species (such as tea) include woody and herbaceous perennials that require only periodic maintenance. Type II species (such as banana) include annuals, biennials and perennials that require frequent maintenance. The cost for maintenance of Type II species is more than for Type I species (Jarret and Florkowski, 1990).

Table 8.8. Estimated Costs Involved in the Storage of Germplasm in the Active Collection (Field Genebank)

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year[a]
Tea				
Land costs	200	4.55	15.167	0.306
Farm equipment	100	2.27	7.567	0.153
Manpower	400	9.09	30.30	0.607
Miscellaneous	100	2.27	7.567	0.153
Total	800	18.18	60.606	1.212
Banana				
Land costs	100	2.27	75.667	1.53
Farm equipment	100	2.27	75.667	1.53
Manpower	200	4.54	151.23	3.06
Miscellaneous	100	2.27	75.667	1.53
Total	500	11.35	378.231	7.59

[a] Distributed over a period of 50 years

Maintenance of plants in field genebanks is labor-intensive and expensive. Along with this, the chance of losing germplasm is very "high due to insect/pest attacks, disease outbreaks and natural calamities. To avoid the loss of vigor as well as to prevent the incidence of attacks by pests, the plants have to be replanted routinely, and this adds up to the further costs. The costs of land and farm equipment (tractor, row-disk bedder, seed spreader, harvester, etc.) contribute to the fixed cost. The manpower required for various farm practices is allocated depending on (a) the nature of the crop and (b) the number of accessions to be handled further on. The expenditures incurred for various agrochemicals (such as pesticides, insecticides, fertilizers, etc.) have been included as miscellaneous expenditures. While calculating the total cost of conservation of germplasm, the storage and maintenance cost in the field genebank have been distributed over a period of 50 years (see Table 8.8).

Costs for Management of Base Collections

In the base collections, the germplasm is conserved employing three approaches: (a) seed genebanks for orthodox seeds, (b) tissue culture repositories for vegetatively propagated plants and (c) cryobanks for recalcitrant seeds as well as the aseptic cultures maintained in the tissue culture repositories.

Seed Genebank

The seed for the base collections is stored in the long-term storage modules maintained at a temperature of –20°C. When received in the genebank, the accessions are screened to remove the undersized, shriveled, diseased and immature seeds; the clean and healthy seeds are subjected to the seed germination test, following the recommendations of IBPGR (now IPGRI) (Ellis et al., 1985). The accessions showing more than 85% viability are transferred into muslin cloth bags and are allowed to equilibrate at a temperature of 15°C and 15% RH in the seed dryer to attain a moisture content in the range of 3–7%. The dried seeds are hermetically sealed in a tri-layered aluminum foil pouch. These pouches are transferred to the long-term storage modules after appropriate labeling, indicating the crop, genus, species, accession number, identification number, germination percentage, moisture percentage, storage date and source.

Table 8.9. Estimated Costs Involved in the Storage of Germplasm in the Base Collection (Seed Genebank)

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year[a]
Paddy				
Consumables	600	13.64	2.728	0.055
Equipment	800	18.18	3.63	0.073
Manpower	700	15.91	3.182	0.064
Miscellaneous	1,000	22.73	4.545	0.092
Contingency	1,000	22.73	4.545	0.092
Total	4,100	93.19	18.63	0.376
Sorghum				
Consumables	500	11.36	3.787	0.076
Equipment	500	11.36	3.787	0.076
Manpower	500	11.36	3.787	0.076
Miscellaneous	500	11.36	3.787	0.076
Contingency	500	11.36	3.787	0.076
Total	2,500	56.8	18.935	0.38
Cowpea				
Consumables	200	4.55	15.167	0.306
Equipment	300	6.82	22.720	0.460
Manpower	150	3.41	11.367	0.230
Miscellaneous	100	2.27	7.567	0.153
Contingency	100	2.27	7.567	0.153
Total	850	19.32	64.388	1.302

[a] Distributed over a period of 50 years.

The various components contributing to the fixed costs are the storage module, arrangements for an alternative power supply, seed germinators, incubators, analytical balances, seed dryers, sealing machine, etc., whereas the manpower and the expenditure on the miscellaneous items, such as germination paper, baskets, labels, glassware, aluminum foil pouches, muslin cloth bags, etc., contribute to the variable cost component. The cost involved in the conservation of seeds with orthodox seed behavior has been distributed over a period of 50 years (see Table 8.9).

The seed genebank aims to store good quality seeds and maintain viability of the accessions above 85%. Therefore, approximately 10% of the accessions kept in the long-term storage are randomly monitored periodically (every 10 years). If on testing it is found that the viability has fallen below 85%, a request is sent to the active site to regenerate the accession for replacement in the base collection.

Tissue Culture Repositories

Conservation of germplasm through tissue culture is a costly exercise and requires expensive equipment and skilled staff. Raising of aseptic cultures, employing shoot tip, nodal segments, zygotic or somatic embryos, is a prerequisite for this activity. For the conservation, emphasis is placed on slowing down the growth of the tissue in cultures to extend the subculture interval. Slow growth under in vitro conditions is accomplished by adopting various strategies: (i) the maintenance of cultures on the minimal media, (ii) the reduction in sucrose quantity in the culture media, (iii) incubating the cultures at low temperatures, (iv) use of osmotic agents (sorbitol, mannitol) and (v) use of growth retardant (ABA, maleic hydrazide, etc.) (Mandal et al., 2000).

The conservation activity begins with the standardization of protocols, which contributes to the cost substantially. The required equipment, including a stereomicroscope, autoclaves, laminar flow cabinets, refrigerators, growth chambers and weighing balances, contributes to the fixed costs, while the manpower, miscellaneous items and the contingency for the maintenance of equipment and facilities contribute to the variable costs. The maintenance of germplasm requires frequent sub-culturing, which adds to the cost involved in its further maintenance (Epperson et al., 1997). For banana and tea, the total cost is calculated on an annual basis, as frequent sub-culturing is required to maintain the viability of the germplasm. The tissue culture activity related to tea germplasm has recently begun with the standardization of protocols. At present, it is not practically employed for conservation purposes, but offers a promising potential to be used in the future (see Table 8.10).

Table 8.10. Estimated Costs Involved in the Storage of Germplasm in the Base Collection (In Vitro Repository and Cryopreservation)

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year[d]
Tea				
In Vitro Repository				
Preparing costs	300	6.82	22.720	22.720
Equipment	300	6.82	22.720	22.720
Manpower	200	4.55	15.167	15.167
Miscellaneous [a]	100	2.27	7.567	7.567
Contingency [b]	100	2.27	7.567	7.567
Total	1,000	22.73	75.741	75.741
Cryopreservation				
Preparing costs	300	6.82	22.727	0.460
Equipment	300	6.82	22.727	0.460
Manpower	200	4.55	15.151	0.306
Miscellaneous [c]	100	2.27	7.575	0.153
Contingency [b]	100	2.27	7.575	0.153
Total	1,000	22.73	75.755	1.515
Banana				
In Vitro Repository				
Preparing costs	50	1.14	38.000	38.000
Equipment	300	6.82	227.200	227.200
Manpower	150	3.41	113.670	113.670
Miscellaneous [a]	50	1.14	38.000	38.000
Contingency [b]	50	1.14	38.000	38.000
Total	600	13.65	454.87	454.87
Cryopreservation				
Preparing costs	50	1.14	38.000	0.767
Equipment	300	6.82	227.200	4.600
Manpower	100	2.27	75.667	1.530
Miscellaneous [c]	50	1.14	38.000	0.767
Contingency [b]	50	1.14	38.000	0.767
Total	550	12.51	416.667	8.331

[a] Maintenance of culture room, equipment,
[b] Consumables, glassware and chemicals.
[c] Maintenance of cryobanks, equipment.
[d] Distributed over a period of one year for in vitro repository and 50 years for Cryopreservation.

Cryopreservation

This technique involves the conservation of germplasm at the ultra low temperature of-196°C using liquid nitrogen. The small-sized recalcitrant seeds are preserved as whole seeds, while in large-sized seeds (such as tea), the excised embryonic axes are conserved. The cultures raised in vitro can be cryopreserved employing encapsulation/dehydration, vitrification or freeze injury methods (Chaudhary and Radhamani, 1993).

The cost incurred in the standardization of protocols contributes substantially to the total cost. The costs involved in the conservation of banana (conserved in the form of cultures) are higher, as this is a prerequisite to the establishment of aseptic cultures, while in the case of tea, the excised embryonic axes can be conserved.

The setting up of the cryopreservation facility requires expensive equipment, such as cryotanks, cryocans, laminar flow, autoclave, analytical balances, stereomicroscopes, analytical balances, etc. It is a highly labor-intensive activity, and the manpower, general laboratory glassware, liquid nitrogen and chemicals contribute to the variable costs.

The cost components involved in cryopreservation have been distributed over a period of 50 years (see Table 8.10), as the accessions once kept in cryotanks are believed to remain viable for an indefinite period. The cryopreservation activities related to banana germplasm have recently begun with the standardization of protocols. At present, it is not practically employed for conservation purposes, but offers a promising potential to be used in future.

Epilogue

In the present study, the cost of conservation has been calculated keeping in mind all of the activities involved in a holistic manner rather than laying emphasis only on the mode of storage, as was done in some earlier studies. The cost of conservation is found to be highly dependent on the crops to be conserved, the mode of reproduction and storage as well as the extent of diversity (see Table 8.11). Among the five test crops, the cost of conservation is least for paddy. This is due to its self-pollinating nature, orthodox seed behavior as well as large number of accessions, which can be handled in the same infrastructure. The various conservation activities require specialized personnel and basic infrastructure. Therefore, the cost effectiveness of the conservation center will be determined by the number of accessions and the strategy adopted for their conservation.

However, there are various limitations encountered in calculating the cost of conservation:

- The activities associated with the conservation of crop genetic resources are highly interlinked, and the research institutions involved do not find it easy to maintain their internal accounts, either commodity-wise or activity-wise. A sense of hesitation in sharing the accounts also exists, as it is looked upon by the institutions as an auditing of their activities. Thus, one has to impute the commodity-wise expenditures by working out the unit cost of each activity, and this calls for making assumptions based on the experiences of the concerned scientists.
- The costs of characterization have in the past included primarily the agronomic and biological Characterization generally using the standard descriptors based

on the requirements of breeding programs, mainly aiming at increasing the production. There is a need for the characterization of germplasm based on social and local knowledge and for specific requirements of communities. This has implications for cost calculations, as it requires compiling this data for the accessions during collection missions and characterizing both existing and newly acquired germplasm. Expenditures will also be required for capacity building and for reorienting the germplasm explorers to this dimension of characterization.

- The passport data sheets will also need to be redefined, and new parameters will have to be included with the changing times, e.g., food processing quality, which is becoming an important criterion of the global economy as well as the national economy, has not been included in existing formats. The cost of identi fying such characteristics will be very high in the absence of local knowledge. The initial expenditure for the modification of the passport data sheets and collation of this knowledge may be high and may need to be accounted for in the future.
- The scientists are using the latest techniques, such as in vitro cultures, cryopreservation, etc., for the conservation of germplasm. This requires costs for protocol development and associated basic studies as well. The costs in the present studies have been calculated using existing models for the crops for which these have been developed. But one has-to treat these estimates as tentative, since actual costs may be high, depending on the technique employed and the nature of the germplasm to be conserved.
- The costs of sharing data with local communities for enabling them to access the same data in times of need have not been calculated in this study. However, one must note that access to the information as well as to germplasm kept in ex situ genebanks must also be provided to the local communities as and when they need them. This would be a very potent incentive for them to share their information and material. Translation will be required for genebank associated databases in local languages, making them available on the Internet for access through public kiosks, etc., all of which will be quite costly given the size of germplasm holdings in the genebank. Though this cost has not been included in the present analysis, this is a cost that will have to be included at some stage to make the interactions between genebanks and people ethically accountable and sustainable in the long-term.

Table 8.11. Total Estimated Costs Involved in the Conservation of Germplasm of Paddy, Sorghum, Cowpea, Tea and Banana

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year [a]
Paddy				
Acquisition of germplasm	5,300	120.45	24.126	0.486
Evaluation and characterization of germplasm:				
- Agronomic evaluation	2,750	62.49	12.5	1.25
- Biochemical and for special traits	4,200	95.45	19.1	1.91
- Molecular evaluation			113.63	2.27
Germplasm health evaluation	3,500	79.54	15.9	0.319
Storage of germplasm:				
- in active collections	3,950	89.78	17.951	1.796
- in base collections	4,100	93.19	18.63	0.376
Common costs	175,890	3,997.38	1.49	1.49
Total	199,690	4,538.28	223.33	9.89
Sorghum				
Acquisition of germplasm	4,100	93.18	31.045	0.622
Evaluation and characterization of germplasm:				
- Agronomic evaluation	2,150	48.87	16.29	1.629
- Biochemical and for special traits	2,700	61.36	20.44	2.044
- Molecular evaluation			113.63	2.27
Germplasm health evaluation	2,050	46.6	15.526	0.310
Storage of germplasm:				
- in active collections	2.800	63.6	21.18	2.118
- in base collections	2,500	56.8	18.935	0.38
Common costs	175.890	3,997.38	1.49	1.49
Total	192.190	4,368	238.54	10.863

Table8.11.(cont.)

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year [a]
Cowpea				
Acquisition of germplasm	960	21.82	72.716	1.468
Evaluation and characterization of Germplasm:				
- Agronomic evaluation	500	11.36	37.88	3.788
- Biochemical and for special traits	1,150	26.14	87.14	8.714
- Molecular evaluation			113.63	2.27
Germplasm health Evaluation	950	21.59	71.961	1.444
Storage of germplasm:				
- in active collections	800	18.18	60.574	6.058
- in base collections	850	19.32	64.388	1.302
Common costs	175,890	3,997.38	1.49	1.49
Total	181,100	4,115.788	509.69	26.53
Tea				
Acquisition of Germplasm	1,950	44.30	147.62	2.983
Evaluation and characterization of Germplasm:				
- Agronomic evaluation	800	18.18	60.61	6.061
- Biochemical and for special traits	1,200	27.28	90.94	9.094
- Molecular evaluation			113.63	2.27
Germplasm health Evaluation	900	20.46	68.188	1.374
Storage of germplasm:				
- in active collections	800	18.18	68.201	1.212
- in vitro repository	1,000	22.73	75.755	75.755
- in cryopreservation	1,000	22.73	75.755	1.515
Common costs	175,890	3,997.38	1.49	1.49
Total	183,540	4,171	702.19	101.754

Table 8.1 1. (cont.)

Apportioned costs head	Rs. (,000)	USD (,000)	USD / accession / year	USD / accession / year [a]
Banana				
Acquisition of germplasm	790	17.95	597.49	23.922
Evaluation and characterization of germplasm:				
- Agronomic evaluation	650	14.78	492.66	49.266
- Biochemical and for special traits	350	6.95	265.01	26.501
- Molecular evaluation			113.63	11.36
Germplasm health evaluation	1,850	42.05	1,401.22	140.12
Storage of germplasm:				
- in active collections	500	11.35	378.231	7.59
- in vitro repository	600	13.65	454.87	454.87
- in cryopreservation	550	12.51	416.667	8.331
Common costs	175,890	3,997.38	1.49	1.49
Total	181,180	4,116.618	4,121.268	723.456

[a] Distributed over the duration of the activity.

References

Breese, E.L. (1989): Regeneration and multiplication of germplasm resources in seed genebanks. The Scientific background. International board for Plant Genetic Resources, Rome.

Bretting, P.K. and D.N. Duvick (1997): Dynamic conservation of plant genetic resources. Advances in Agronomy 61. Pp. 1-51.

Bellon, M. (1996): The dynamics of crop intraspecific diversity: A conceptual framework at the farmer level. Eco. Bot. 50. Pp. 26-39.

Brush, S. (1991): A farmer-based approach to conserving crop germplasm. Eco. Bot. 45. Pp. 153-165.

Chaudhary, R. and J. Radhamani (1993): Cryopreservation of seeds of orthodox and recalcitrant seed species. In: Rana, R.S., R.K. Saxena, S. Saxena, and V. Mitter (eds): Conservation and Management of Plant Genetic Resources. NBCROP DIVERSITY, New Delhi. Pp. 330-331.

Clay, J. (1991): Cultural survival and conservation: Lessons from the past twenty years. In: Commonwealth of Australia (1993): Biodiversity Series. Paper No 1. Dept. of Environment, Sports & Territories, Canberra.

Ellis, R.H., T.D. Hong and E.H. Roberts (1985): Handbook for seed technology for genebanks. Vol 1: Principle and Methodology. International board for Plant Genetic Resources, Rome.

Epperson, J.E., D.H. Pachico and C.L. Guevara (1997): A cost analysis of maintaining cassava plant genetic resources. Crop Science 37. Pp. 1641-1649.

FAO (1995): The State of Food and Agriculture. Rome.

FAO (1996): Report of the International technical Conference on Plant Genetic Resources, Leipzig, Germany, 17-23 June 1996.

Fingleton, J. (1993): Conservation, Environmental protection and Customary land tenure. In: Alcorn, J. (ed): Papua New Guinea Conservation Needs Assessments. Biodiversity Support Program, Washington DC. Pp. 31-56.

Gupta, A.K. (1995): Compensating Local Communities for Conserving Biodiversity: How Much, Who Will, How and When. Also published as Rewarding Local Communities for Conserving Biodiversity: The Case of the Honey Bee in Protection of Global Biodiversity. In: Lakshman, D., Guruswamy and Jeffrey A. McNeely (eds): Converging Strategies. Duke University Press, Durham and London. Pp. 180-189, 1998. IIMA Working Paper, No. 99-10-04, October 1999.

Harry, J.P., R. Ortiz, E. Arnaud, J.H. Crouch, R.S.B. Ferns, D.R. Jones C. Mateo n Picq , and D. Vuylsteke. (1997): Banana and Plantain. In: Paroda, R.D., R.K. Arora., and K.P.S. Chandel (eds): Plant Genetic Resources - Indian Perspectives. Proc. Of Nat. Sym. On PGR, organized by NBPGR at New Delhi, NBPGR. Pp. 67-81.

Heywood, V.H. and I. Baste (1995): Introduction. In: Heywood, V.H. (executive ed): Global Biodiversity Assessment. Cambridge Univ. Press, Cambridge. Pp. 1-19.

Hill, S.B. and J. Ramsay (1977): Weeds as Indicators of Soil Conditions. The McDonald Journal, June 1977, Volume 38 (6). Pp. 8-12.

Iyer, C.P.A. and T.R. Subramanian (1988): Genetic resources activities concerning tropical fruit plants. In: Paroda, R.D., R.K. Arora, and K.P.S. Chandel (eds): Plant Genetic Resources - Indian Perspectives. Proc. Of Nat. Sym. On PGR, organized by NBPGR at New Delhi, NBPGR. Pp. 310-319.

Jackson, M.T., G.C. Loresto , S. Appa Rao, M. Jones, E.P. Guimaraes and N.O. Ng (1997): Rice. In: Fuccillo, D., L. Sears and P. Stapleton (eds): Biodiversity in Trust - Conservation and use of Plant Genetic Resources in CGIAR Center. Cambridge Press. Pp. 273-291.

Jarret, R.L. and W.J. Florkowski (1990): In vitro active vs field genebank maintenance of sweet potato germplasm: Major cost considerations. HortSci. 25. Pp. 141-146.

Krishna, S. (1998): Gender and biodiversity management. In: M.S. Swaminathan (ed): Gender Dimensions in Biodiversity Management. Konark Pub. Pvt. Ltd., Delhi. Pp. 23-61.

Mandal, B.B., R.K. Tyagi, R. Pandey, N. Sharma and A. Agrawal (2000): In vitro conservation of germplasm of agri-horticultural crops at NBPGR: An overview. In: Razdan: M.K. and C. Cocking (eds): Conservation of Plant Genetic Resources In Vitro. Vol. 2: Applications and Limitations, Science Publishers Inc., USA & Oxford & IBH Publishing Co., New Delhi. Pp. 279-307.

Martin, G.J. (1995): Ethnobotany. Chapman & Hall, London.

Myers, N. (1994) Protected Areas - protected from a Greater What? Biodiversity and Conservation 3. Pp. 411-418.

Nabhan, G. (1996): Conservation and forest service join forces to save wild chilies. Diversity 6. Pp. 47-48.

Ng. N.O. and B.B. Singh (1997): Cowpea. In: Fuccillo, D., L. Sears and P. Stapleton (eds): Biodiversity in Trust - Conservation and use of Plant Genetic Resources in CGIAR Center. Cambridge Press. Pp. 82-90.

OECD (1996): Saving Biological Diversity - Economic Incentives. France.

OECD (1999): Handbook of Incentives Measures for biodiversity - Design and Implementation.

Pardey, P.G., B. Skovmand, S. Taba, M.E. Van Dusen and B.C. Wright (1998): The cost of conserving maize and wheat genetic resources ex situ. In: Samle, M, (ed): Fanners, genebanks, and crop breeding: Economic analyses of diversity in wheat, maize and rice. Kluwer Acad. Pub., USA.

Pardey, P.G., B. Koo, B.D. Wright, M.E. van Dusen, B. Skovmand and S. Taba (1999): Costing the Ex Situ Conservation of Genetic Resources: Maize and Wheat at CIMMYT. EPTD Discussion Paper 52. Washington, D.C.: IFPRI, 1999.

Porceddu. E. and G. Jenkins (1991): Seed regeneration of cross-pollinated species. A.A. Baikema, Rotterdam.

Primack. R.B. (1993): Essentials of Conservation Biology. Sinaurer Associate Inc. USA.

Ram Nath (1993): Plant quarantine procedures in relation to germplasm movement. In: Rana. R.S., R.K. Saxena, S. Saxena and V. Mitter (eds): Conservation and Management of Plant Genetic Resources, NBPGR, New Delhi. Pp. 39-45.

Sharma. S.D., A. Krishnamurthi and S.R. Dhua (1988): Genetic diversity in rice and its utilization in India. In: Paroda, R.D., R.K. Arora and K.P.S. Chandel (eds): Plant Genetic Resources - Indian Perspectives. Proc. Of Nat. Sym. On PGR, organized by NBPGR at New Delhi, NBPGR. Pp. 108-120.

Singh, I.D. (1988): Genetic resources in tea. In: Paroda, R.D., R.K. Arora, and K.P.S. Chandel (eds): Plant Genetic Resources - Indian Perspectives. Proc. Of Nat. Sym. On PGR, organized by NBPGR at New Delhi, NBPGR. Pp. 435-442.

Singh, R.K., P.L. Gautam, S. Saxena and A. Singh (2000): Scented rice germplasm: conservation, evaluation and utilization. In: Singh, R.K., U.S. Singh, and G.S. Khush (eds): Aromatic Rice. Oxford & IBM Pub. Co. Pvt. Ltd., New Delhi. Pp. 107-134.

Stenhouse, J.W., K.E. Prasad Rao, V. Gopal Reddy and S. Appa Rao (1997): Sorghum. In: Fuccillo, D., L. Sears, and P. Stapleton (eds): Biodiversity in Trust - Conservation and use of Plant genetic Resources in CGIAR Center. Cambridge Press. Pp. 292-308.

Tan, A. and A.S. Tan (1998): Data Collection and Analysis in Turkey: GEF Project on In situ Conservation of Genetic Diversity In: Jarvis, D.I. and T. Hodgkins (eds): Proceedings of a Workshop to develop tools and procedures for in situ conservation on on-farm. P. 31.

UNEP (1992): Global biodiversity strategy: guidelines for action to save, study and use earth's biotic wealth sustainably and equitably. Convention on Biodiversity. UNEP, Geneva.

UNEP (1995): Global Biodiversity Assessment. Cambridge Univ. Press, Cambridge.

Virchow, D. (1999): Genetic resources: Status, development, losses and conservation management. In: Conservation of Genetic Resources - Costs and Implications for Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. Springer. Pp. 11-44.

Wood, D. (1993): Forests to Fields: Restoring tropical lands to agriculture. Land Use Policy 10. Pp. 91-107.

World Conservation Monitoring Center (WCMC) (1992): Global Biodiversity: Status of the earths living Resources. In collaboration with the National History Museum, London in association with IUCN, UNEP, WWF, WRI. Chapman & Hall, London. Pp. 1-3.