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PROVIDING FARMERS' RIGHTS THROUGH *IN SITU* CONSERVATION OF CROP GENETIC RESOURCES

by

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1. EXECUTIVE SUMMARY

The purpose of this paper is to show how the needs for conservation and equity can be joined and resolved through internationally sponsored programs for in situ conservation of crop germplasm. The paper has two major conclusions. First, in situ conservation is a viable and necessary addition to the existing strategies to preserve plant genetic resources for agriculture. The second major conclusion is that market financing, whether through intellectual property or contracts is untenable for financing plant genetic resource conservation for agriculture. This paper recommends financing farmers’ rights and in situ conservation through a multilateral trust fund.

The importance of plant genetic resources for agriculture make it imperative that effective conservation mechanisms be established. The United Nations Convention on Biological Diversity (CBD) has moved the world community into a new era of managing and conserving its biological resources. The CBD gives major emphasis to in situ conservation. While off-site (ex situ) conservation in gene banks is an essential component of preserving vital crop resources, conservation must go beyond this, to maintain the evolutionary processes that create the resource. In situ conservation provides a way to improve conservation and to recognize the important role of farmers in maintaining and providing resources to the world community.

The paper is divided into four major sections. The Introduction is in Section 1. Section 2 concerns in situ conservation of crop genetic resources. This section examines the importance of in situ conservation, the complementarity of this strategy with ex situ (gene bank) conservation, and the relation between conservation and equity. Section 3 outlines a program of in situ conservation, emphasizing institutional strengthening, community programs, and incentives to farmers. Section 4 discusses two different approaches for funding in situ conservation: (1) a market approach involving intellectual property mechanisms and/or contracts and (2) a non-market approach involving a multilateral trust fund. This paper endorses the latter. It concludes with a discussion of the scope of funding appropriate for in situ conservation as one means to recognize farmers’ rights. Farmers’ rights are here defined according to the International Undertaking on Plant Genetic Resources (FAO 1989), as the right to recognition for contributing to the common welfare by providing genetic resources.

2. INTRODUCTION

Crop germplasm is arguably the most important of the Earth’s biological resources for humans. It is the foundation of all food production, the key to feeding unprecedented numbers of people in times of climate and other environmental change. The value of crop germplasm is vastly increased by the rapid growth of the human population and the limited amount of new agricultural land. Future human welfare depends on improved crop conservation, especially including farmers in the international effort. Demand by science and industry for crop germplasm is likely to increase because of biotechnology. On-farm conservation will help maintain the evolutionary processes that generate crop genetic resources, and it will acknowledge the contribution of special farming cultures to the welfare of people everywhere. Once lost, genetic resources that have evolved over millennia are irrecoverable.

Increased food production must come in large part from increased productivity, and crop germplasm is the cornerstone in achieving higher yields. Crop improvement requires a stable and continuing source of crop germplasm. Yet, the source of crop germplasm is endangered [Harlan 1975; Hawkes 1983; National Research Council (NRC) 1993; Esquinas-Alcázar 1993]. This source is the populations of wild and weedy crop relatives and landraces of ancestral and local crop varieties. The threat to crop germplasm is genetic erosion, as wild vegetation is eliminated for fields and pasture and as older varieties are replaced by new ones. The underlying causes of genetic erosion include population increase, economic restructuring and technological change.

Throughout the 20th Century, crop germplasm has been collected from centers of crop diversity. This germplasm is stored in a network of national and international institutes (gene banks), concentrated in industrial countries of the northern hemisphere (Plucknett et al. 1987). The creation of an international system to conserve crop germplasm is an important accomplishment, but two factors require us to extend conservation beyond the confines of gene banks. First, it is necessary to maintain evolutionary processes that generate new germplasm. Second, it is necessary to recognize the contributions and interests of farmers, who have provided invaluable germplasm resources to the world community, so that they may continue to do so. In situ conservation is a strategy to address both evolutionary processes and equity.

3. IN SITU CONSERVATION OF CROP GENETIC RESOURCES

During the ten millennia in which humans have produced food, they have developed the original domesticated plants into complex populations with tremendous phenotypic and genetic diversity (Harlan 1992; Zohary and Hopf 1988; Esquinas-Alcázar 1993). With some important exceptions, diversity is usually concentrated in regions where domestication occurred (Harlan 1992; Harris and Hillman 1989). This concentration derives from the presence of wild ancestors and hybridization, environmental heterogeneity, and long-term crop evolution and human selection. There are four distinct categories of crop germplasm: (1) wild crop progenitors and relatives, (2) semi-domesticated (weedy) crop relatives, (3) landraces of ancestral crop species and (4) modern crop varieties. Duvick (1984) notes that genetic diversity in time may also be considered as another category. Wild crop relatives, belonging to related genera and species, represent the primary stock genetic material, but until the invention of modern plant breeding methods and genetic recombinant technology, this germplasm was relatively inaccessible. Weedy relatives are a bridge between domesticated and wild plants, often dwelling at the borders of fields and uncultivated land. Modern crop varieties may have little contribution as genetic resources, owing to their origin and uniformity.

Landraces are genetically diverse forms of cultivated plants, a subset of biodiversity at the interface between wild plant species and domesticated species that are manipulated by humans. Landraces provide the bulk of crop germplasm that has been collected and stored in gene banks, and landraces are a primary breeding material in crop improvement programs. They are the ancestral populations of modern crop cultivars, comprised of locally named (folk) varieties, most of which are restricted in geographic distribution (Harlan 1992). These local varieties are often phenotypically and genetically distinct and very diverse. For instance, the International Potato Center in Lima, Peru has over 6,500 potato varieties in storage, and the International Rice Research Institute in Manila has 78,000 rice accessions in storage, mostly local varieties from farms (Plucknett et al. 1987).

Landraces are the legacy of hundreds of generations of farming people in cradle areas of domestication. Regions of agricultural diversity are alike in having farming systems that are localized in terms of knowledge, the use of few commercial inputs, and an orientation toward subsistence production (Brush 1991). Structural and political conditions such as inequitable land distribution, unfair terms of trade, ethnic domination, and political disenfranchisement have been emphasized as determinants of farming systems where genetic diversity is concentrated (Fowler and Mooney 1990).

The diversity of landraces comes from hybridization between crops and their wild relatives over long periods and from human and natural selection of crops over thousands of generations in diverse environments. Crop diversity does not persist as an incidental characteristic of farming systems but because farmers choose to maintain different crops and crop varieties. The systematic nature of farmer nomenclature for landraces has been documented as evidence of their thorough knowledge of crop resources (Boster 1985; Brush 1992). Agronomic advantage of diverse rather than homogeneous crop inventories is found in many areas. For instance, farmers in Chiapas Mexico keep distinct landraces of maize that are suited to specific soil conditions and to work schedules of the farm household (Bellon 1991; Bellon and Taylor 1993). Cultural reasons (e.g. ritual, cuisine, or aesthetics) apply in other farming systems, such as in Southeast Asia where rice landraces are associated with family lineages (Dennis 1987). Elsewhere, economic advantage is associated with high market value. In Peru, for instance, potato landraces are marketed for high prices in urban markets (Brush, Taylor and Bellon 1992).

Plant genetic resources for agriculture are a unique type of biological resource because of the mutual dependence of humans and the plants on each other. The importance of crop genetic resources was recognized long before the rise of modern genetics. Thomas Jefferson observed that “the greatest service which can be rendered any country is to add a useful plant to its culture, especially a cereal or oil seed.” (Baron 1987). Farmers and gardeners of many cultures take great pride in the diversity of cultivars under their care. Exchange and introduction of new crops and germplasm have fueled demographic and economic revolutions in many places (Salaman 1949; Crosby 1972). Most crops perform far better outside their place of origin than within, a fact that has affected the pattern of world agriculture and trade (Jennings and Cock 1977). Industrial and non-industrial nations alike have benefited from open access to new crops and varieties. The world diet has been radically changed and immeasurably improved by the free movement of food plant resources. Maize, a New World crop, became the staple in many parts of Africa. Potatoes spread from the Andes not only to Europe but also to Asia and Africa. Rice from Asia followed a similar course in South America. The same benefits from free exchange also pertains to industrial crops and to medicinal plants (Brockway 1988). Coffee, an African domesticate, fueled a new economy in South America, and quinine from South American plants is used to combat malaria in Asia and Africa.

3.1. Importance of in situ conservation

Crop genetic resources are threatened by land conversion, the diffusion of high yielding crop varieties and other technological changes (Hawkes 1983; Harlan 1975). The Food and Agricultural Organization of the UN began activities concerning plant genetic resources in 1947. The international plant genetic resource conservation system now includes a network of national and international facilities to store, characterize, distribute and use crop germplasm (Plucknett et al. 1987). Conservation became an international priority because of the value of germplasm to increased crop production, rapid population growth, and the recognition that genetic resources were limited and decreasing (Frankel and Bennett 1970). The international system of crop germplasm conservation is of great value to the primary users of crop genetic resources in private, national and international crop improvement programs. Nevertheless, a sense of dissatisfaction and ferment on the periphery of the system is found. The ferment concerns the long-term prospects for conservation and equitable participation in the benefits of conservation by nations and farm groups who originally supplied the germplasm to gene banks. In situ conservation of crop genetic resources is a means to address the concern over long-term conservation and equity between nations in the benefits of conservation.

In situ conservation is defined scientifically as the maintenance of crop genetic resources in their natural habitat (Oldfield and Alcorn 1987; Brush 1991; Friis-Hansen 1994). The United Nations Convention on Biological Diversity defines in situ conservation as

> "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. " (in Reid, et al. 1993).

For wild species, habitat maintenance may require setting land aside as a biological preserve. For landraces, habitat maintenance means conservation in farmers' fields. This does not require that entire farms or farming systems be sown with landraces. On-farm conservation can take place on single parcels of different farms and in a small portion of a total farming system.

In situ conservation was rejected by the original planners of the international crop germplasm system, but it is now perceived as a counterpart and a possible solution to problems encountered with ex situ conservation. Ex situ conservation is biologically problematic because it does not allow for the evolutionary processes that created crop germplasm (Hamilton 1994). The concentration of stored genetic resources in industrial countries and the lack of recognition of the contribution of less developed countries and their farmers are politically troublesome to some (Fowler and Mooney 1990). In situ conservation can address both of these problems.

The current status of in situ conservation policy is best characterized as benign neglect, and this characterization is mirrored in the science of crop conservation (NRC 1993). Virtually all public resources for conservation are directed to ex situ methods. While in situ conservation might be acknowledged as possible and perhaps necessary, there are exceedingly few efforts in any region of crop evolution to plan or implement in situ conservation. This benign neglect approach is, however, unsatisfactory. Since the mid-1980s there has been an increasing clamor for broader participation in conservation activities and access to the economic value embodied in genetic resources (e.g. Mooney 1983; Fowler and Mooney 1990). The transfer of genetic resources from less developed countries to industrial ones has raised concern about the need to balance the interests of industrial users (public breeding programs, international agricultural research, and seed companies) and farming communities in gene-rich environments (Fowler and Mooney 1990). A strong mutual interest exists in conserving germplasm, yet this mutual interest cannot be served without a two-way flow (germplasm - financial resources) between less developed countries and industrial countries. The United Nations Convention on Biological Diversity (CBD) is strong evidence of the shift of political winds to greater participation by farmers in conservation (Reid et al. 1992; Krattiger et al. 1994).

Three premises have delayed the acceptance of in situ conservation as a strategy for preserving crop genetic resources. First, it was assumed that in situ conservation was an anomaly in farming systems undergoing modernization, since farmers must sacrifice genetic resources in order to adopt modern technology or to increase food and income production (Ford-Lloyd and Jackson 1986). Second, it was assumed that ex situ conservation was sufficient to the task of preserving crop germplasm. Third, it was assumed that in situ methods and ex situ methods were somehow antagonistic. These premises are invalid. The first two are discussed below, and the third is treated in the next section.

3.1.1. Maintaining crop evolution

The notion that in situ conservation is antithetical to agricultural modernization results from the idea that premodern farming systems were stable and unchanging (Frankel 1970). This idea holds that a steady state of crop evolution has been upset by recent technological and social changes. The conclusion that in situ conservation is antithetical to modernization is mistaken because of the flawed assumption that a steady state existed before modern times. The interaction of genetic, human, biotic and physical systems makes a steady state impossible to achieve or maintain in a farming system. Rather, change in this evolutionary context is continuous, and homeostasis is illusory. This means that farming systems with landraces have constantly adjusted and kept landraces to meet new conditions, and we can expect them to adjust in the future.

In its fullest sense, the conservation of crop genetic resources must go beyond gene banks to maintain the evolutionary processes that create crop germplasm (Oldfield and Alcorn 1987; Altieri and Merrick 1987). The ex situ conservation of crop genetic resources has saved genes that would otherwise be lost, and it has made genes accessible to plant breeders for crop improvement. Ex situ conservation is, however, unable to preserve the biological processes that generate and select new crop germplasm (Frankel and Soulé 1981). The spatial and temporal dimensions of crop evolution cannot be held in gene banks, and without these, evolution ceases. Needs of the future may not be addressed by ex situ conservation, especially if major environmental changes occur or if there is genetic drift within collections.

The maintenance of crop evolutionary processes in key farming systems is important for several reasons. The evolution of agricultural systems does not cease after genes are put into off-site collections. Climate continues to change, pests and pathogens evolve, and physical conditions, such as soil chemistry and structure, change. Crop evolution is the natural system whereby new types of crops arise through genetic recombination, mutation, and hybridization within and between cultivated and wild plant populations. Geneticists are able to replicate and accelerate these processes in the laboratory, but the amount of natural diversity in field conditions is greater than the amount achieved through artificial crosses.

Crop evolution is best understood in Darwinian terms, with attention to both natural and conscious selection (Donald and Hamblin 1984; Rindos 1989). The evolution of crops might be toward a particular ideotype, as both natural and conscious selection favor certain phenotypes (Donald and Hamblin 1984; Fischbeck 1991). Yet, diversity persists because of the heterogeneity of natural and conscious selection. The great amount of diversity that has arisen after the genetic bottleneck of domestication suggests that a tendency toward diversity is as strong as one toward a crop ideotype (e.g. Jana and Pietrzak 1988). Diversity is a product of selection in many different natural and human environments, but it may also reflect a universal human preference. This preference may give way to technological transformation in some situations, as in the U. S. corn belt, but the instances of such transformation may be exceptional and unlikely to be repeated in regions of crop domestication.

The specific nature of the evolutionary process depends, of course, on the crop in question. An outcrossing crop such as maize will be greatly affected by hybridization. Conscious selection is likely to be important where seed is individually or intensively managed, for instance in potato cultivation. Conscious selection is likely to be less important in crops where seed is harvested in bulk and broadcast in planting, for instance with wheat. Conscious selection is often assumed to emphasize agronomic characteristics (Donald and Hamblin 1984), although non-agronomic attributes may be equally or more important (Boster 1985; Brush 1992). Competition between genotypes may be inversely related to within-field diversity (Donald and Hamblin 1984), itself a function of seed management and conscious selection. Exchange between farms is predicated on the existence of distinct local crop varieties and knowledge of those varieties among farmers.

Crop evolutionary processes (hybridization, competition, local selection and exchange) flourish in farming systems where farming practices do not isolate cultivars from wild and weedy relatives or other cultivars. Introgression between wild relatives and cultivars can be an important aspect of outcrossing crop species, such as potatoes (e.g. Rabinowitz et al. 1990). Other important characteristics that promote diversity are a degree of physical and economic isolation, dependence on local inputs, production for local consumption rather than for market, and local knowledge systems of the crop, its biotic and physical environment. These conditions depend on environmental and socio-economic heterogeneity and perhaps on the persistence of cultural and economic autonomy at the local level.

Crop evolution thus provides an on-going source of crop germplasm that can be included in crop improvement programs. Moreover, natural and human selection can occur in many more contexts than is possible in agricultural experiment stations. Agricultural scientists can improve their craft by understanding the basic ecology of crops in natural settings and by learning from farmers. The knowledge base of farming cultures which have managed complex collections of crop varieties is a very valuable resource, both to other farmers and to biological scientists. The value of farmer knowledge is reflected in a growing literature on indigenous knowledge and participatory agricultural research involving both farmers and scientists (e.g. Richards 1985; Marten 1986; Gupta 1992).

3.1.2. Conservation practices of farmers

Case studies demonstrate that farmers in different regions of crop diversity maintain genetic resources even though they have also adopted modern agricultural technology (Brush, Taylor and Bellon 1992; Bellon and Taylor 1993; Dennis 1987). Factors such as land fragmentation, marginal agronomic conditions in hill lands, distance from markets, and cultural identity affect the selection of local and exotic crop varieties and lead to the conservation of genetic resources. Case studies of farmer conservation of landraces suggest that population increase and spatial integration of production systems have had three effects on the cultivation of local crop populations (Brush, Taylor and Bellon 1992). First, the area of cultivation of landraces has been greatly reduced, to as low as 10% of the crop area in some regions. Second, the areas of cultivation of local crops have become fragmented into islands interspersed among larger areas of improved crop cultivars. Third, local landraces have disappeared from certain portions of the farming system. Landraces that were adapted to optimal conditions are particularly vulnerable. Farmers keep local landraces in areas that are relatively marginal, characterized by poorer soils, steeper slopes and higher altitudes. Landraces from optimal areas that have disappeared in the field are likely to be found in gene banks. The impact of these three changes on the overall amount of genetic diversity and on evolutionary processes of crops is not known.

Shrinking area for traditional and local crops is the major cause for genetic erosion, yet the theoretical basis for this concern is problematic. Biogeography (MacArthur and Wilson 1967) predicts that a decrease in area and increasing fragmentation should depress the level of biological diversity. Yet, several features of crop ecology may limit the value of this prediction in the case of crop populations that experience decreased area and fragmentation. Biogeographic analysis is not yet adapted to assess the effect on diversity of conscious selection and management. Estimating this effect requires us to evaluate the relative contribution of human and natural selection to crop population structure. Moreover, biogeography theory is derived for inter-species diversity, while crop evolution includes intra-species diversity. In addition, population issues, such as minimum viable population and inbreeding depression, may not be relevant for crops that are self-pollinated or maintained as clones. Menges (1991) finds that many aspects of biogeographic theory, such as genetic stochasticity, demographic stochasticity, and minimum island size, are not particularly pertinent to in situ conservation of wild plants. They are likely to be even less important for cultivated plants.

It is unknown whether the existing pattern of farmer maintenance of landraces will persist into the future. It may persist indefinitely or it may succumb to the pressures of population increase and spatial integration of dispersed farming systems. A concerted public and international effort to support in situ conservation can guarantee its persistence. An effort to support and sustain in situ conservation can only succeed if the economic gains to the farmer are greater with local crop varieties than gains from adopting exotic varieties or converting land from crop production to other uses.

The object of in situ conservation is not to preserve a steady state or stable crop population structure but rather to preserve the processes of crop evolution, defined by hybridization within and between populations of wild, weedy and cultivated plants, competition among genotypes, natural and conscious selection at the local level, and exchange of different genotypes among farms. Of fundamental importance here is the idea that in situ conservation will not be a sector-wide phenomenon in a nation's agricultural sector, but focused on key regions of crop biological diversity. The success of in situ conservation rests on the competitive advantage of landraces in particular farming systems.

This vision is one of islands of crop conservation surrounded by other regions where modern varieties predominate. A critical planning task for in situ conservation is to identify the regions and scope where crop evolutionary processes can be maintained by working with carefully selected farming communities. Another planning element is to estimate the viability of different sized islands of genetic resource conservation. The susceptibility of genetic resource islands to pests or diseases or to environmental shifts must be determined.

3.2. Complementarity between of in situ and ex situ conservation

From the early years of the 20th Century, nations have embarked on a program to save crop resources in gene banks. Ex situ conservation was given priority and remains valid because pockets of genetic diversity are at risk and their resources are relatively inaccessible for use by breeders and geneticists (Cohen et al. 1991). However, in situ maintenance is now being examined more critically as a complementary conservation method (Jana 1993, Shands 1991). Gene bank protocols are likely to lead to genetic shifts, so that material stored therein may vary considerably from the original populations (Hamilton 1994).

Rather than directly providing genes for crop improvement, in situ conservation should be seen as satisfying four other needs. First, in situ conservation preserves evolutionary processes that generate new germplasm under conditions of natural selection. Rare alleles and genotypes may be particularly difficult to locate and include in gene banks, and the cost of collecting and preserving them may be very high (Hamilton 1994). In situ conservation may conserve rare alleles and genotypes at a relatively low cost, although the cost of recovering them might be high. Farmer-based conservation may serve as a back-up to gene banks to insure against loss of genetic resources because of technological failure or financial cut backs. Second, in situ conservation will maintain important field laboratories for crop biology and biogeography. Third, it provides a continuing source of coadapted germplasm for ex situ collections. Over time, collections in gene banks may only preserve a small fraction of crop genetic resources. Finally, support for in situ conservation would help to satisfy the need for the inclusion and recognition of farmers who have heretofore been overlooked (Keystone 1991). This conservation approach provides a means for wider participation in the international effort, allowing for a more equitable role for nations with abundant crop germplasm resources.

Several factors limit the ability to estimate the success of capturing genetic variability. Record-keeping in collection has often been inadequate; small numbers of plants were collected; some ecogeographical areas have been inadequately sampled (especially in less accessible areas); and poor management may have led to loss of genetic variability in collections (NRC 1993). Moreover, since only a small percentage of crop collections has been adequately described and studied, we have little factual basis for estimating total possible variability within and outside of collections. Logically, more variability has arisen in farmers' fields after the time of collection.

The capture and preservation of rare alleles and genotypes is an important objective of any conservation strategy (Marshall and Brown 1975). Common and widespread alleles and genotypes are by definition not threatened and not objects of conservation. Locally common alleles and genotypes are of special value for crop improvement (Marshall and Brown 1975; NRC 1993), yet the effort and cost to obtain these alleles may be very high. In situ conservation may permit conservation of alleles that are otherwise too costly to collect, including alleles that have emerged since collection. In situ conservation is only warranted, however, if the genes that are saved in farmers fields in conservation areas are accessible to plant collectors and crop improvement programs. This accessibility can be built into in situ conservation programs by providing a closer and on-going connection between farmer-based programs and gene banks connected to crop improvement institutes.

3.3. Sharing benefits: conservation and equity

A broad consensus exists among scientists, politicians and the public that biological resources are both very valuable and endangered (NRC 1993). While value and scarcity are linked, each has led to somewhat different concerns. Attention to value has, for instance, led to discussions about fair treatment for people who nurture and provide those resources to industrial users (e.g. Mooney 1983; Posey 1990). Attention to the scarcity of biological resources led to conservation programs (e.g. Frankel 1970; Plucknett et al. 1987). The inevitable conjoining of value and scarcity gives rise to the idea that compensation for biological resources can address both equity and conservation (Reid et al. 1992; Sedjo 1988, 1992; Keystone 1991; Rubin and Fish 1994). Conservationists and advocates for farmers' interests have proposed that traditional farmers with crop genetic resources be compensated for providing industrial users access to those resources (Posey 1990; Sedjo 1992; Rubin and Fish 1994). The goals for doing this would be to provide incentives for conservation and equitable recognition to stewards of biological resources.

Crop genetic resources are maintained by all types of farmers, but the uneven diffusion of modern technology may concentrate these resources among poor, peasant farmers who are often ethnic minorities (Nabhan 1989). Since Vavilov' s pioneering work in the early 20th Century, the economic benefit of crop genetic resources to industrial nations is recognized (Vavilov 1951, Harlan 1975, Cox, Murphy, and Goodman 1988, Kloppenburg and Kleinman 1988). Industrial nations generally are outside the regions where crops were domesticated and where crop genetic resources are common. Therefore, industrial nations have depended on exotic germplasm for their agricultural development. Moreover, commercial enterprises have arisen in industrial countries around the breeding and distribution of new crop varieties, and these enterprises depend to some degree on germplasm from less developed countries. Commercial breeding, however, is only a fraction of the professional breeding that feeds the world. Major food crops, such as wheat and rice, have little or no commercial breeding. In virtually all breeding efforts, public breeding is an important source of germplasm. The immediate source of germplasm may be gene banks in industrial countries or international agricultural research centers, but the original source may have been peasants' fields in less developed countries. Intellectual property for plant varieties exists in many industrial nations and in some non-industrial ones (Jondle 1990; Hamilton 1993), but comparable protection does not apply to the folk varieties kept by farmers.

While seed companies in industrial countries can profit from excluding others from using their product without compensation, farmers have no such recourse. In other words, genetic resources in farmers' fields are treated as a public good or common heritage, while genetic resources in industrial laboratories may be treated as private property. Farmers lack the legal means to patent their crop resources, to exclude others from using, or to share in financial profits from using them. Farmers lack these means because of the wide distribution of genetic resources, the existence of public collections with large amounts of germplasm, and ambiguity about the source, uniformity, and novelty of resources in farmers' fields. It is unlikely, therefore, that farmers will find patenting an effective means to generate financial benefits from their plant genetic resources.

The existence of plant breeders' rights in industrial countries and the lack of farmers' rights is particularly important in the international discourse on the inequity of the existing system and the need to recognize farmers' rights. Equity and compensation for farmers are now firmly established objectives in discussions of the fate of crop genetic resources (e.g. Keystone 1991). Equity refers to the quality of being fair or balanced; compensation means to counterbalance, make up for, or make amends (Oxford English Dictionary 1971). These terms, however, have been used in two different ways in discussions of crop genetic resources. To some, equity and compensation refer to fair treatment of farmers and nations who have given their genetic resources in the past(e.g. Mooney 1983; Kloppenburg and Kleinman 1988). Those who stress the inequity of the current system usually downplay the importance to less developed countries of germplasm from industrial countries and international agricultural research. To others, the terms equity and compensation refer to the basis for future relationships (e.g. Swanson, Pearce and Cervigni 1993; NRC 1993). Those who stress future needs emphasize the importance of defining mutual interests in developed and less developed countries.

The United Nations Convention on Biological Diversity recognizes the imbalance between industrial countries that use genetic resources and less developed countries that provide them. A new Undertaking on Plant Genetic Resources sponsored by the FAO also recognizes this imbalance. This imbalance might be redressed in three ways. First, industrial countries might give up their intellectual property right to monopolize elite germplasm (breeding lines) that uses landraces from farmers' fields. This is a return to a universal common heritage system, and it was proposed as part of the initial Undertaking on Plant Genetic Resources (FAO 1989). A variant of this proposal would be to share intellectual property rights or benefits derived from elite germplasm with countries that provided genetic resources used in the elite germplasm. Second, countries with biological diversity may design a new form of intellectual property for landraces and other genetic resources in situ. This might be a variant of plant variety protection or utility patents found in industrial countries. Third, industrial countries might provide compensation to providers of genetic resources in recognition of the global benefit that has resulted from these resources.

The first solution, limiting intellectual property in industrial nations is untenable. Intellectual property is firmly entrenched in industrial nations and will be increasingly common and uniform following the successful conclusion of the negotiations for GATT (Global Agreement on Tariffs and Trade) in 1993. The second solution, creating a new intellectual property system for farmers and their genetic resources is impractical. The design of sui generis systems of plant protection allowed under GATT will follow patterns already established, which do not allow protection for genetic resources per se as intellectual property. Sui generis systems will look like plant variety protection and utility patent protection in industrial nations; protection not designed for farmers. Intellectual property protection for elite germplasm is little different from other types of intellectual property, since public resources (scientific theories, unprotected ideas, biological resources) are often manipulated and changed in the laboratory to create new property (Merges and Nelson 1990). Germplasm resources have only recently been defined as national patrimony; their source is often ambiguous; they are often the result of discovery rather than invention; and collective invention is more important than individual invention. There is little chance that landraces can satisfy the common criteria for intellectual property for plants: novelty or uniqueness, the result of non-obvious procedures, uniformity, and stability.

The third solution to the inequity of the status quo of germplasm collection and use is to establish a system of compensation whereby industrial users agree to support a system of material recognition of the role of farmers in LDCs. This is the most feasible of the three methods proposed to redress the inequalities between industrial users and peasant producers of genetic resources. This compensation, however, must be seen not only as a way to recognize farmers but as a way to provide mutual benefit to both producers and users of genetic resources. In other words, compensation enables the sharing of two distinct benefits: crop genetic resources from farmers' fields and economic benefits from using these genetic research laboratories. Compensation should not be defined as payment for past services but for future options.

Compensation to farmers for crop genetic resources can resolve three complementary problems: (1) biological resources are public goods, (2) their fate is external to the current cost/benefit accounting of economic development, and (3) there is a tendency to underinvest in their conservation (Sedjo 1988; 1992). The public good concept is, however, susceptible to changing conditions of science and to declining resources (Demsetz 1967). Compensation for biological resources is a possible means to incorporate traditional farmers and indigenous people into the world economy while at the same time strengthening local cultural knowledge and resource management, steps often seen as incompatible (Fowler and Mooney 1990).

The creation of a system for compensating farmers for biological resources is, however, fraught with problems. Much of the current literature on the topic fails to weigh competing interests in the control and exploitation of biological resources. It is unclear whether compensation can best be accomplished via market or non-market means. Little attention has been given to the potential impacts of market methods (intellectual property or contracts) on local farm communities or indigenous groups. The nature of markets for biological resources is poorly understood. Likewise, the efficacy of privatizing genetic resources as a means to conserve them is unknown. Non-market systems have not been fully described or analyzed.

Compensation, in the form of payment to farmers or in some other material transfer from industrial to less developed countries, may be seen as a way to balance historic inequalities between poor farmers and industries who have collected crop germplasm and privatized breeding lines. This formulation is retrospective or post hoc because it seeks to redress historic inequalities. Matching the value gained from crop genetic resources requires that payment to farmers or less developed countries be based on resources previously collected and appropriated. This theme is echoed in most of the discussions of compensation for genetic resources (e.g. Kloppenburg and Kleinman 1990, Mooney 1983).

Retrospective equity is, however, problematic for several reasons. First, it focuses on only one exchange out of a multiplicity of flows of technology, knowledge, and capital. A “balance sheet” of benefits that flow between countries is all but impossible to construct. For example, farmers in less developed countries may produce both landraces (genetic resources) and improved varieties that have used germplasm and human capital from industrial countries. Second, crop germplasm has historically been treated as a non-rivalrous or public good, because collection of seed samples in no way decreases the availability of genetic resources to the farmers who provided it. The origin of a large percentage of germplasm in storage is unknown or ambiguous. Third, crop germplasm is usually a product of collective invention, often involving farmers of different regions and nations. Compensation to one farmer, community, or nation may arbitrarily ignore the contributions of others. Fourth, payment for past inequities does not necessarily address the future or create a lasting incentives for those who provide genetic resources and those who use them. Finally, compensation for past collection does not benefit the particular farmers who originally provided the germplasm. For these reasons and others (Swanson, Pearce and Cervigni 1993; NRC 1993) retrospective compensation has been largely rejected by the international community as a basis for recognizing the contributions of farmers in maintaining, creating, and providing crop genetic resources.

A more positive approach to equity is grounded in conservation theory and the notion of internalizing the value of genetic resources into the overall budget of agricultural research and production (Sedjo 1988; Norgaard and Howarth 1991; Cumberland 1991). This approach argues that the real balance (equity) is to recognize the value of genetic resources and the costs of conserving them that are borne by particular individuals, regions or nations. Because genetic resources are public goods and treated as common property (non-exclusionary, common heritage), farmers who cultivate them cannot benefit directly from their genetic value. Rather, farmers who have traditional crop genetic resources often have good reasons to abandon them in order to change technology to produce more food or income. Farmers who keep genetic resources may forego the opportunity to increase food production or income, yet there is no current method to offset this opportunity cost and to reward them for conservation. Hence the problem of genetic erosion. Since genetic resources are public goods, society has a tendency to underinvest in their conservation and to treat them as externalities as long as they remain in farmers' fields.

The most tractable imbalance is between the inconstant and often unrecognized value of genetic resources to the world community and the cost to farmers and less developed nations for keeping them. This perspective replaces retrospective equity value with the value of future use or conservation equity for future use. A balancing of equities in this sense is to compensate farmers for the cost of keeping genetic resources for the future benefit to other consumers and farmers. The equities involved in this formulation are the opportunity costs of conservation on the one hand and the use value of crop germplasm in public and private agricultural research on the other. Opportunity costs to farmers who maintain genetic resources are the costs of lower productivity or lower income from traditional crop varieties in comparison to modern ones. Equity for conservation requires that these opportunity costs be recompensed by those who use and benefit resources that are conserved.

While equity for conservation appears to be straight forward, it raises a number of difficult and unresolved issues. Equity for conservation can be established by either market or non-market methods. This paper argues that non-market methods are the more effective and fair means. The most efficient and equitable method for arranging compensation or support for in situ conservation is not determined and may vary from country to country. Which nations and regions should be compensated is unresolved, as is the number of farms needed for effective in situ conservation. The level of compensation needed to implement in situ conservation is likewise unknown. Equity for conservation implies that the level of compensation must consider both the value of the genetic resource and the costs of conserving it. Finally, measures that will lead to in situ conservation must be identified and evaluated.

4. IMPLEMENTING IN SITU CONSERVATION

In situ conservation is not conceived here as a mass program aimed at all farms or farmland in regions of crop diversity. It is not conceived as an alternative to crop improvement through the diffusion of improved cultivars that replace local or traditional cultivars. Rather, in situ conservation is a program aimed at carefully selected communities and farms. It is based on the idea that crop resources and evolutionary processes can be kept on islands of traditional agricultural systems that are linked to off-site conservation. An important quality of this strategy is that it does not require direct competition or choice at the national level between conserving traditional crop cultivars and crop improvement through breeding and diffusion of new cultivars.

In situ conservation requires the collaboration of farmers, non-governmental organizations, national agricultural research programs, and international agricultural research centers. Sufficient numbers of farmers must be attracted to the idea of in situ conservation so that enough cropland in critical crop environments can be kept in landraces and wild species. Direct incentives, such as markets, and indirect incentives, such as education, must be used to encourage farmer participation. Farm advocates in non-governmental organizations (NGOs) and scientists in both governmental facilities and NGOs must serve as partners to farmers, to identify the necessary area and number of farms for conservation activities and to monitor the success of these activities. Scientists and farmers can be complemented by extension agents to plan and implement community-based conservation programs linked to ex situ efforts.

Like other concepts for sustainable agricultural development, in situ conservation depends on a relatively low input of capital equipment but a relatively high input of human capital, for training, scientific research, and networking among farm communities, scientists, and policy makers. One essential difference between in situ and ex situ conservation is that no single, master plan or technology is possible for in situ conservation. Rather, a resilient and flexible approach is needed to plan national and local strategies for different crops and for farming conditions that may change in the future. Three core tasks must comprise any in situ conservation program: (1) to strengthen institutions; (2) to select target regions and farming communities and therein establish community-based conservation activities; and (3) to identify a menu of approaches to provide incentives to farmers to maintain landraces and wild crop resources.

4.1. Institutional strengthening

An essential ingredient of in situ conservation is a community of scientists, extension agents, and farmers who are well trained, equipped and motivated to pursue in situ conservation objectives. This community requires an institutional base linked to the broader crop conservation and agricultural development sector. National agricultural research services (NARS) must be able to identify localities or regions where significant crop genetic resources remain intact. National programs must also be able to assess the threat of genetic erosion to these resources. Specialists in both the formal and non-formal (NGO) sectors must be able to employ different methods to avert these threats through education and other community programs, agricultural development using crop diversity, and economic incentives. Institutional flexibility is required since no single approach will work for all crops or regions or over time. Conservation services in the agricultural sector must be able to frequently adapt their approach and strategy, in the same manner as successful agricultural development services.

Institutional capacity and flexibility in planning and implementing in situ conservation can be built and sustained in three ways -- research, training, and linkage between the formal and non-formal (NGO) sectors. A primary focus of international funding should be to develop institutional capacity in NARS for conservation activities. Support for this strengthening can come from international sources, including such centers as the International Services for National Agricultural Programs (ISNAR) and the International Plant Genetic Resource Institute (IPGRI).

4.1.1. Research

A prerequisite for in situ conservation is to develop the agricultural research capacity in biological and social sciences to provide technical back-up and collaborative support to farmers, extension agents and NGOs. Policy makers, farm groups and NGOs must be assisted in identifying critical conservation priorities and areas, monitoring crop resources, providing production alternatives to crop substitution, and identifying and evaluating policy options. However, the agricultural research capacity of national programs in regions of crop genetic diversity is insufficient to meet the requirements of in situ conservation. Understanding the processes of genetic erosion and conservation requires a base of expertise across several fields of science -- genetics, botany, agronomy, ecology, anthropology, and economics. One challenge crop scientists is to understand long-term social and biological processes with limited temporal data. Another challenge is to combine the methodologies of different areas of science that are concerned with genetic resources. Institutional capacity to meet these challenges is necessary for planning and implementing conservation programs. Scientists must assess the threat to genetic resources and monitor the success and future needs of conservation programs.

Three types of research should be part of in situ projects. The first is ethnobotanical and socio-economic research to understand and analyze patterns of farmer knowledge, selection, utilization and maintenance of crop genetic resources. Initially, the ethnobotanical research will rely on anthropological methods to describe the base of farmer knowledge regarding local crops. Subsequently, social, cultural and economic factors will be quantitatively measured and used to analyze the patterns of conservation and loss of genetic diversity on different farms and in different communities. Questions that will be addressed will be the influence of farm size, commercialization of production and use of external inputs. By understanding these factors, this research will help determine how changes such as increased population or improved markets will affect the selection and maintenance of local crop varieties.

The second type of research is in the population and conservation biology of local crops. This research seeks to understand the structure and dynamics of genetic diversity in landraces. It will involve studies on the distribution and extent of genetic diversity in the target crops and areas and provide a base for continuing studies of change in diversity over time. This research will help determine the distribution of genetic resources among different farms and regions, the risk of genetic erosion, and optimal sampling and collection strategies, both for in situ and ex situ conservation. It will provide invaluable baseline information to monitor future change in genetic resources. A significant feature of the work will be the linkages developed between the ethnobotanical and the population and conservation biology aspects. This will allow integrated conclusions on conservation strategies which take into account both social and biological factors.

In addition to the contributions of ethnobotany and population biology, in situ conservation will also benefit from a new direction in crop improvement research. Research in mass selection or recurrent selection is a promising means to increase crop yields without losing local crop biodiversity. Improvement of productivity has two components: improving agronomic practices and improvement of the landraces themselves. It is widely known that landraces harbor considerable genetic diversity. This diversity can form the basis for selection of improved types without disrupting the locally adapted gene complexes, thus conserving the features of local types held dear by the local communities. Such selection can be applied at appropriately placed experimental fields or in farmers' fields. Classical methods of population improvement by mass and family selection can be used, and also specific genes may be introgressed by backcrossing and selection. Breeding procedures could be developed that promote the introgression of wild germplasm into the cultivated gene pool. These procedures should be adaptable for the transfer of high and low heritability traits.

International funding for a 5 to 10 year period will enable national agricultural research institutions to establish research in ethnobotany, population biology and crop improvement for planning, implementing and monitoring in situ conservation. The practice of this research will equip national agricultural research institutions to continue this activity after the life of the project. The continued ability to carry on research in these areas will be a lasting contribution to the national infrastructure and human capital in science.

4.1.2. Training

The second component of institutional strengthening is training, aimed at four different groups: scientists, technical support staff, extension agents, and farmers. The objective here is to build a broad base of expertise in crop conservation. At the scientific level, in situ conservation projects should support advanced degree work at both the M.Sc. and Ph.D. levels in population biology, ecology and social science. The strategy here is to train a group of scientists who will focus specifically on crop resources and who will assume leadership positions in conservation programs in national agricultural research services.

Technical support staff will complement the work of scientists in such areas as data management, geographic information systems (GIS), and biochemical analysis (isozyme) for population research. This technical staff is an essential element in the long-term ability to monitor genetic resources.

Extension agents working in the crop conservation sites comprise the third group for training. The object of this training is to increase extension agents' knowledge of crop identification, selection and seed maintenance skills. These skills will be critical in helping farmers to improve local crop selection and to maintain unique crop varieties on their farms. Extension agents can receive training at national agricultural research facilities. It is expected that their interest and involvement in the project will act as a stimulus to farmers to improve selection and in situ conservation. Extension agents will also provide an important bridge between national agricultural research staff and farmers.

Farmers are the fourth group to be trained under in situ conservation projects. Training should emphasize enhancing the identification of plant traits, selection, utilization and maintenance of local crops. One important skill is to train farmers in selection of plants in the vegetative state rather than after harvest. Training can take place both in the communities selected for the in situ project activities and at national agricultural research service facilities.

4.1.3. Communication and networking

A cooperative linkage between scientists, extension agents and farmers is an important ingredient for all levels. National agricultural research services depend on information flow from the farm level to succeed in their research and conservation missions. Extension agents depend on information from both research centers and farmers, and farmers are eager to receive technical information and assistance. The research and training elements discussed above will provide numerous opportunities for these three groups to communicate and share knowledge. Moreover, in situ conservation projects should formalize this communication by holding regular workshops at both the regional and national levels. Finally, major seminars at three to five year intervals should bring outside experts into the project.

4.2. Community-based conservation programs

The second broad strategy to achieve the objective of establishing in situ crop conservation will be to organize community projects in selected regions. Criteria for selecting these regions may include the presence of diverse and valuable plant genetic resources and evidence of a significant threat of genetic erosion. One project that has been initiated in Ethiopia is the creation of a network of community gene banks (Worede 1992). These community gene banks can be linked together in national networks, with advice and technical support from the institutions discussed above. Community education and participation in demonstrations and agricultural fairs is another activity. Participation in local crop improvement through mass selection and recurrent selection is a third type of community based activity in support of in situ conservation.

Community gene banks provide a means to organize local support for conservation, train farmers in conservation activities, build a low cost and low maintenance storage facility, and link farmers, extension agents and national program staff. A first step is to contact local leaders and farmers in selected districts and communities and to organize a local association to work with the extension agents and scientists in initiating the work of the community gene bank. In situ project funds might be used to build a multi-purpose facility for the community gene bank. This facility might have rooms for seed storage, seed selection, documentation/administration, and community meetings and training sessions. It can also include a garden area for local plants that cannot be stored as seed.

Community storage is already practiced in some areas of crop genetic diversity, for instance in Ethiopia as a method to provision seed in times of stress. The community gene bank builds on this tradition. Farmers can store a portion of their seed in the community gene bank. This seed will be available for retrieval at any time. A small, but representative population sample of seed will be taken from selected stocks for storage as a genetic resource at the community gene bank, with a duplicate sent to the national program facilities.

Major incentives to the farmer in the operations of the community gene bank will be the increased training and presence of extension agents. These experts will not only be available to select and store local seed and genetic resources but also to work with farmers in improving crop production. Extension agents and scientific staff will be able to advise farmers on the advantages of different crop varieties (local and introduced) and where various ones might do well. These experts will be able to help farmers increase production by improved crop management techniques such as plant selection.

NGOs can play an essential and pivotal role in community-based activities (Cooper, Vellvé and Hobbelink 1992). NGOs are valuable partners with scientists, extension agents, and farmers. Existing in situ conservation programs, for instance in the Philippines, Chile, and Ethiopia, depend to a large degree on the leadership and support of popular and non-governmental organizations. These organizations (SEARICE in Philippines, CET in Chile) have generated support from farmers, governments and the public. They have begun to identify strategies for farmer-based and community conservation of crop resources. While the biological efficacy of their efforts is not yet established, their social efficacy is an important contribution. It is important to note, however, that the prevalence and strength of NGOs is uneven. NGOs are absent or play insignificant roles in some important regions of crop genetic diversity, for instance in Turkey and Mexico.

Measures to identify successful NGO programs, to strengthen the leadership capacity of these programs, and to facilitate their outreach are valuable components of community-based in situ activities. NGOs must be encouraged to share their ideas and approaches with other interested parties in crop conservation, namely national and international agricultural research programs. A format for evaluating in situ conservation must be established, with the collaboration of agricultural researchers in NGOs and NARS. This collaboration depends on the creation of a common forum where NGOs and NARS scientists do not perceive themselves as antagonists or rivals. Collaboration between agricultural researchers can be promoted through mutual training opportunities.

The human resource capacity of NGOs can also be strengthened by improved networking capabilities to link NGOs working in different regions and countries. Cross training among NGOs with different approaches is relevant. This can be accomplished through training in communications, enhancing publication, telecommunication and electronic communication facilities in NGO offices, and providing the financial means for workshops.

4.3. Incentives to farmers

The third broad strategy of a farmer-based conservation program is to identify and provide non-market and market incentives for growing landraces. Farmers themselves must perceive an advantage in continuing to grow traditional crops, and their participation in conservation of landraces must be self sustaining (sustainable). This last condition requires a minimum of centralized support or subsidy to specific farmers or farm groups. In other words, continuing in situ conservation cannot rely on direct production subsidies to farmers. Landrace production and utilization is important for farming communities in many regions of diversity and will continue to make a substantial contribution to national agriculture in those regions. In situ conservation programs can address and impact both incentives and disincentives that influence farmer conservation. Non-subsidy incentives can have an important impact on maintenance of landraces. It is important to identify where agricultural production and pricing policies are likely to act as disincentives to continuing use of landraces. A key issue relating to incentives is scale: defining and achieving the critical area needed to conserve crop genetic resources in situ and at an affordable public investment.

4.3.1 Non-market incentives

Among the significant non-market issues that should be addressed are the availability of seed and the current status and level of informal seed exchange. Another non-market incentive would be public acknowledgment of the value of the genetic material and knowledge of farmers. This acknowledgment is possible through a variety of approaches such as agricultural fairs that emphasize local diversity, community prizes, extension and education programs. Agricultural research can be brought to bear on seed storage and viability of landraces. Networks of seed exchange can provide both new seed and strong incentives for saving older varieties, as documented in Europe and North America (Cooper, Vellvé and Hobbelink 1992; Nabhan 1989). At a broader level, the institutional strengthening and community activities mentioned above will greatly elevate the awareness of landraces and their value. More directly, conservation projects can also develop educational material and programs at regional agricultural fairs to illustrate the wealth and importance of crop genetic diversity.

4.3.2 Market incentives

Market incentives have been identified as a tool to encourage conservation (McNeely 1988). Strategies to meet both conservation and economic goals in tropical forest conservation have included designating special areas for mixed-use, selective cutting rather than clear-cutting in forests, and developing markets for forest products such as fruits, nuts, resins and medicinals (Redford and Padoch 1992). An advantage of these strategies is that they rely on and reinforce the environmental knowledge of local people in threatened habitats (Anderson and Ioris 1992; Nations 1992). The market can play a positive role in conservation, by providing additional income to farms that produce landraces or value added status to products that use them (Brush, Taylor, and Bellon 1992). In many parts of the world, landraces already have special market niches in urban areas, commanding higher prices than other crop varieties. The keys to a market incentive program are to identify specific constraints that limit continuing landrace utilization by farming communities and their capacity to market landrace products at local, national and international levels. A contribution of a conservation program would be the identification of special consumer products that utilize landraces, which might include botanical coffee varieties, snack foods, flour, and breakfast cereals. Non-governmental organizations in several areas have succeeded in creating "green marketing" and "green labeling" programs, especially for organically grown products and sustainable harvest tropical forest products. This success suggests that a similar approach could be extended to landraces.

The extent to which existing local and national marketing opportunities could be developed and the major constraints (transport, communication, market opportunities, etc.) that are currently operating need to be identified. Green marketing is a strategy that recognizes the potential of special urban markets to support local conservation programs in rural areas where low income and other marginal economic conditions make conservation too costly for farmers. Green marketing for traditional crop products is supported by the fact that urban consumers in both developed and developing countries are often willing to pay higher prices for traditional crop products. There is a potentially large international market for products that have social values such as conservation and the support of disadvantaged farmers. In the United States, for instance, there are good markets for "organically produced" tropical products such as bananas and coffee that are produced by farmer cooperatives. Green marketing has proven itself as a viable strategy in specialized tropical products for condiments (e.g. Ben and Jerry's Ice Cream) and the personal hygiene industry (e.g. The Body Shop). The stability and durability of these specialty markets is hard to anticipate, and if they are unstable or short-lived, then conservation goals could be jeopardized. Thus, green marketing should be seen as but one of several strategies to provide incentives to farmers.

A system of green labeling can be created to identify products that meet social and conservation goals in agriculture. A system of appellations that authenticate landrace origin might be based on the successful use of this system in many national and international markets. Landrace conservation and support for traditional farmers who maintain genetic resources are logical extensions of the appellation idea.

Finally, in situ conservation projects can help identify national policies and trends that may adversely affect on-farm conservation in the future. Examples of such policies include credit provisions that require the use of improved crop varieties, crop insurance restrictions, and price subsidies for certain varieties. The purpose of an in situ conservation program cannot be to reorient national agricultural policy at a sector-wide level. Rather, it should be to identify policies that adversely affect landrace conservation and to address this conflict in the specific regions selected for conservation activities. For instance, it is possible that credit restrictions affecting landraces could be suspended for designated communities or regions. Designating conservation areas can lead directly to identifying land use policies and practices (e.g. urbanization, deforestation, over-grazing) that negatively affect genetic resources.

4.4. Institutional framework

National agricultural research services, international agricultural research centers, multilateral agencies, national environmental protection agencies, and non-governmental organizations have interest in and can contribute to in situ conservation of crop genetic resources. Two institutional issues confronting in situ conservation will be considered briefly: (1) the relationship between the formal and non-formal sectors and (2) the relationship between national and international programs.

4.4.1 Formal and non-formal sectors

Linkage and collaboration between formal sector institutions (NARS) and non-formal sector institutions (NGOs) is an essential element for successful in situ conservation programs. In many countries, NARS already manage genetic resource collections, while NGOs have close links with farming communities. Linkage to university programs is specially important. Without exception, the agricultural research capacity of national programs in regions of crop genetic diversity is insufficient to meet the requirements of in situ conservation. Crop population biology and social and economic science (ethnobotany) are particularly critical and under-supported at present. Universities can play a key role in filling this gap.

Non-formal sector institutions are important in planning and implementing in situ conservation. NGOs have a clear comparative advantage in their experience with in situ conservation. On-site conservation is by definition highly participatory, requiring local support and coordination, and some NGOs may have a valuable experience working with farm groups in conservation (Cooper, Vellvé and Hobbelink 1992). Potential qualities of NGOs are their flexibility and ability to link applied research from different disciplines. In the area of crop conservation, such disparate concerns as genetics, ethnobotany, agronomy, and marketing must be brought together. The disciplinary organization of formal sector institutions may make it difficult for them to manage the fluid demands of combining these concerns into a single program and taking this program to farm communities. NGOs can play a positive role in overcoming this obstacle.

4.4.2. National and international programs

Agencies at both the national and international levels are currently involved in ex situ conservation, and it is essential that both levels be concerned with in situ conservation. Both levels have important contributions to make. National agricultural research programs that manage ex situ collections and crop improvement are logically the key agencies for planning and implementing in situ conservation because they have a comparative advantage in several regards. National programs are familiar with local farming systems where plant genetic resources are found. They are connected to extension and education programs that are critical to the success of in situ conservation. They are knowledgeable of national policies that affect variety choice and with local markets that might be developed for landraces. Finally, the complementarity between ex situ and in situ conservation depends on integrating them into the same institutional structure.

Nevertheless, national programs face several difficulties in planning and implementing in situ conservation programs. Most critically, they lack the financial and personnel capacity. National program personnel often are responsible for both breeding and conservation activities, and breeding is usually a higher national priority. In situ conservation requires new disciplinary and interdisciplinary skills that are rarely found in national programs. Training in conservation biology, population biology, biogeography and crop ecology has not been stressed. Few national programs have sufficient capacity in social science, especially in the areas of ethnobotany or cultural ecology. Finally national program budgets may be inadequate or barely adequate for minimum maintenance of ex situ collections. For instance, base collections are often uncharacterized and infrequently tested for viability. Few national collections have been thoroughly documented with biogeographic or population biology methods, to describe the population structure and distribution of germplasm. Therefore, it is necessary to upgrade national programs to undertake the expanded activities that will be required for in situ conservation.

International agencies, especially international agricultural research centers (IARCs) of the CGIAR system, should play an important complementary role in planning and implementing in situ conservation. IARCs have a comparative advantage that can complement national programs. ISNAR and IPGRI are well situated to support national programs. IARCs may have advantages in training and regional coordination, especially where small national programs are unlikely to develop the local capacity for in situ conservation. Rather than duplicate capacity in such fields as population biology and ethnobotany in every possible national program, IARCs may house this capacity to serve a regional need. Another important role for IARCs is to undertake basic scientific research in support of in situ conservation activities of national programs. This would be comparable to their role in developing the science of seed management. One important area of basic research is to develop rapid and efficient methods to survey biological diversity in order to designate conservation areas. Another area is in the biogeography of conservation regions, to determine optimal size, agroclimatic representation, and linkage between regions.

International agricultural research centers have, in some cases, very good personal relations and rapport with NARS scientists, and this could play a crucial role in motivating interest in in situ conservation. However, whether the top management of both IARCs and NARS understand the concept and are willing to put core resources into in situ conservation activities is another question altogether. Core resources are now devoted exclusively to gene bank activities. Augmented budgets for in situ activities may initially depend on special project funding, but this should only be a bridge to future core funding. A crucial factor is to provide for continued interest and devotion to in situ conservation when special project funding ceases. A cadre of scientists, trained in population biology and ethnobiology and with core support, is important to continued interest. Forming this cadre is a major objective of international support. The FAO and other development agencies can play an important role in developing the human resources necessary for long-term in situ conservation work.

5. FINANCING IN SITU CONSERVATION: A FARMERS’ RIGHTS APPROACH

The in situ conservation program outlined above requires international funding because of practical reasons and concern for equity. Countries and farmers who have genetic resources face costs to keeping them. Conservation itself requires investment, especially in human capital, to undertake the activities outlined above. Industrial countries stand to benefit from this conservation, so it is appropriate that they help finance it. The threat of genetic erosion of crop resources will persist because of population growth, market expansion, and technological change. Continued benefit from plant genetic resources will, therefore, require funding for conservation.

The scheme outlined above avoids direct subsidies to farmers by building incentives to continue established patterns of conservation. It is based on the fact that farmers in areas of crop diversity continue to sow local varieties, even as they adopt new technology and new seeds (Brush, Taylor, and Bellon 1992; Dennis 1987; Bellon 1991; Zimmerer 1991a, 1991b). In situ conservation can strengthen existing practices of farmers with non-market and market incentives to continue maintenance of crop genetic resources. Moreover, relatively small areas and few farms might be sufficient to conserve the habitat of crop genetic resources (Brush, Tayor and Bellon 1992).

We are faced with two related questions about the investment for in situ conservation. The first question is how much will it cost and the second is what is the best way to finance these costs. Two alternatives exist in response to both questions: market and non-market solutions. These two approaches, however, require quite different arrangements, present different costs, and pose different difficulties. There is no current way to firmly estimate the cost of in situ conservation because we have not determined the number of farmers or the extent of land necessary to save a predetermined amount of crop germplasm in the field. Logically, this cost would be in addition to the current investment in ex situ conservation, and future conservation budgets will reflect a balance between the two conservation strategies. It is important to recognize, however, that current investment for plant genetic resource conservation of any type is inadequate (NRC 1993).

5.1. Financing conservation via the market

Market mechanisms are cited as a promising way to fund conservation activities (Sedjo 1988, 1992; Lesser and Krattiger 1994). The advantages of markets for addressing conservation needs relate to their supposed efficiency and democratic basis. Environmental degradation is associated with the treatment of environmental resources as common property and as externalities in the accounting of production budgets. Thus, there is little firm basis for setting the level of public investment for conservation. This can be an acute problem when spending for conservation competes with funding for other areas. Defining environmental resources as commodities and internalizing costs of conservation in production budgets allows the market to set the level of spending. This may not only give a better idea of the willingness of the public to invest in conservation but it may also reduce administrative costs by shifting bureaucratic management of environmental protection to private sector management.

The use of market mechanisms for managing and conserving environmental resources presupposes two things. First, it assumes that environmental resources and conservation costs can be converted to commodities. Second, it assumes that the market will be an effective means for achieving conservation. Both of these assumptions must be thoroughly examined in the context of specific environmental resources and conservation tasks. The following sections will discuss the possibility of commoditizing crop genetic resources as a way to achieve in situ conservation.

Genetic resources in farmers' fields are customarily treated as a public good, and they are viewed as a common heritage whose value is social rather than individual. Using these genetic resources is non-rivalrous because they can be acquired without reducing the stock of resources remaining in a farmer's fields. Moreover, their industrial use is for the common good, such as more abundant and less expensive food. Farmers ultimately may benefit from freely providing genetic resources because of the future availability of new crop varieties. One consequence of defining genetic resources as a public good and common heritage is that no market is developed for them (Wilkes 1987; Sedjo 1992). Another consequence is genetic erosion, the degradation of crop landraces as an environmental resource. The problem of genetic erosion arises because individuals have opportunity costs (lost yield, lower income) and few benefits from selecting local rather than improved crop varieties (Brush, Taylor and Bellon 1992).

Although farmers receive benefits from their common heritage resources, their crops are undervalued as genetic resources. Theoretically this situation can be changed by converting common heritage into private property. Two conventional means exist for turning environmental resources such as crop germplasm from public goods and common property into commodities (Sedjo 1992). First is to adapt the intellectual property system, as was done to protect plant breeders' rights in the U. S. and Europe (Mastenbroek 1988; Jondle 1990; Hamilton 1993). Second is to create a system of contracts between farmers and the users of crop genetic resources, following precedents in biological prospecting for natural pharmaceuticals (Reid et al. 1993).

5.1.1. Intellectual property for farmers' resources

Granting intellectual property is a familiar method for converting public goods into private ones (Demsetz 1967). Intellectual property does not directly convey market value to an idea or plant that is protected. Rather, it allows the market to work where it otherwise would not, by permitting a person to exclude others from using his or her ideas or plants, except under license or royalties. The right to exclude effectively becomes the right to profit from selling the idea or plant. Without intellectual property, all ideas are public goods or common property, and no one can be excluded from using another's idea. The right to temporary monopoly power, however, requires that the claimant of the right prove his eligibility. Defining, contesting, and defending this eligibility pose very high costs.

Defining the crop genetic resources within farmer varieties as a form of intellectual property has a certain superficial appeal. If farmers can exclude others from using their genetic resources, then they may benefit from their efforts to create, identify and preserve genetic resources. The incentive to conserve these resources may be increased if farmers can profit from selling their varieties to seed companies or breeders. Conservation of genetic resources replaces creativity of new ideas as the primary public interest in the application of intellectual property to crop landraces.

Crop genetic resources in landraces and farmer varieties share several characteristics with intellectual goods that are protected as intellectual property. Crop landraces and farmer varieties are non-rivalrous (public goods), so that one person's use of them does not diminish their availability to anyone else. The genetic resources of landraces are often novel and usually have potential utility. They result from the skilled application of local knowledge in managing plant populations and agricultural environments. Crop genetic resources may result from the creative activities of specific persons or groups. Finally, since intellectual property rights exist for other plant material, especially for elite breeding lines, then other classes of crop resources, such as farmers' varieties, might also warrant protection.

Intellectual property over plants generally takes two general forms, plant variety protection and utility patents (Jondle 1990). Plant variety protection allows breeders to register a variety that meets four criteria: novelty, uniformity, stability, and distinctiveness (Jondle 1990). Protection is given for a limited time (e.g. 18 years in the U. S.), allowing the owner to exclude others from selling the variety during this time. Two major exemptions, however, limit the owners' power to exclude others. The breeders' exemption allows breeders to use registered material to create new varieties without paying royalties to the original owner. The farmers' exemption allows farmers to reproduce the variety for seed and to sell that seed as long as these sales are not the major business of the farm (Jondle 1990).

Utility patents are applied to live organisms in a few countries, notably the U.S., and these patents use different criteria (novelty, utility, non-obviousness) and are more restrictive than plant variety protection. Breeders' or farmers' exemptions are not recognized under utility patents. Both plant variety protection and utility patents for plants are created to protect the rights of specific individuals who have manipulated biological resources to create new crop varieties. (Mastenbroek 1988). The recently completed Trade Related Intellectual Property System (TRIPS) agreement of the General Agreement on Tariffs and Trade (GATT) allows nations to design sui generis plant protection methods that use elements from the systems described above.

Plant variety rights or utility patent protection may conceivably be adapted to landraces, or a new and special type of protection may be created for landraces. It is highly unlikely, however, that farm groups with crop genetic resources can use either existing plant variety protection or utility patents to profit from their resources. Farmers' varieties exist in the public domain, and they are usually discoveries of existing plants or the result of "collective invention" -- a type of invention not usually covered by patents (Allen 1983). The sheer volume of different farmer varieties, the fact that genetic diversity crosses national boundaries, and the large amount of genetic resources already collected and placed into the international public domain pose serious difficulties for any one farm group or nation seeking to claim novelty or distinctiveness. Because little is known about phenotype stability of farmers' varieties, geneticists are generally skeptical about folk classification and management at the infraspecific level (Burtt 1970). This skepticism is an obstacle to protecting farmer varieties as intellectual property. Moreover, continued evolution in farmers' fields means that change always occurs. A different standard of stability would be required to protect farmer varieties. Most importantly, farmers' varieties are usually the result of natural processes in cultivated fields rather than non-obvious genetic manipulation. Identification and selection of new varieties by farmers do not constitute invention as defined by intellectual property law. While protection for farmer varieties is conceivable under a sui generis system of plant protection allowed by GATT, conformity to the prevailing modes of plant protection makes it unlikely that farmer varieties will be protected by intellectual property.

5.1.1.1. Intellectual property as a conservation tool

The logic of the intellectual property proposal is to stimulate conservation as part of a profit making scheme. However, several factors greatly weaken this proposal, at least with existing intellectual property methods. The breeders' exemption under plant variety protection means that a farmer or group who claims ownership of a local variety may receive little benefit from geneticists who use the local variety to breed a new commercial variety. This impediment to profiting from landraces is compounded by the allowance for derivatives in most intellectual property. Since plant variety protection allows others to create derivatives, this method may be of very little value to farmers hoping for compensation from breeders.

A second factor has to do with the limited market potential of landraces as genetic resources. Most breeding programs combine genetic material from a wide range of sources, making it difficult to designate the contribution of a single source to the final variety or to its commercial value. While unique genes are sometimes found to have valuable traits such as disease or insect resistance, commercial and publicly bred varieties are not usually based on a single gene. This indeterminacy also weakens the position of farmers who might wish to sell landraces to crop breeders. Landraces are likely to have very little commercial value because of breeders' strong preference for genetic material with known agronomic traits rather than exotic, unknown and unadapted material (Marshall 1989).

The relative abundance of germplasm in public institutions also lessens the possibility that breeders will purchase crop germplasm from farmers. Large national gene banks and those at international agricultural research centers of the CGIAR system (e.g. IRRI, CIMMYT, CIP) control a large percentage of the world's collected germplasm reserves. These institutions have consistently taken a strong stand against commoditizing the germplasm in their collections, through intellectual property or other means (Ayad 1994). Germplasm from these collections is more attractive than germplasm from uncollected landraces to breeders in both industrial and non-industrial countries for several reasons -- including seed health, biological identification, and characterization of agronomic traits. Several studies of the uses of crop germplasm (e.g. Marshall 1989; Peeters and Galeway 1988) suggest that current supplies in international and open collections exceed demand. Since most of the use of genetic resources is by the public rather the private sector, most users are likely to expect a public source for breeding material. The abundance of collected germplasm thus undermines a market based on intellectual property for crop genetic resources. There seems little chance that users will pay for unknown germplasm when they can obtain it without cost from international and open collections.

Finally, the use of intellectual property as a conservation tool will be negatively affected by high transaction costs. Transaction costs are expensies that are incurred in creating and administering intellectual property protection -- establishing a legal infrastructure, monitoring compliance, resolving conflicts. Farmers who claim plant variety for utility patent protection for landraces will be asked to show that their material is distinctive and not already in the public domain. Enforcing these criteria will be very complex and costly as other farmers and public programs will want to contest them. If these criteria are relaxed, the sure result will be an arbitrary benefit to the first farmer, farm group or nation to file. The conservation benefit that may result from intellectual property, therefore, will be greatly dissipated for farm groups with genetic resources but without financial means for legal assistance.

5.1.2. Contracts for biological prospecting

Contracts between producers of genetic resources (e.g. farmers) and private users (e.g. seed companies) are a way to avoid the monopoly-related problems associated with intellectual property. Contracts differ from intellectual property in that they do not establish or imply a monopoly over a specific invention. In theory, they are the easiest means to create a market for genetic resources because they have fewer transaction costs than intellectual property. Contracts between producers and users of genetic resources might take different forms: e.g. licensing or restrictive use provisions (Ihnen and Jondle 1990). Contracts are in fact being written by public agencies and private firms for access to biological resources related to plants with potential medicinal properties. The U.S. National Cancer Institute, Merck Pharmaceutical, and Shaman Pharmaceuticals have negotiated contracts with indigenous groups or national institutes for biological prospecting rights (Reid et al. 1992).

The success of contracts for crop genetic resources depends on the ability of a farm community or nation to control and limit the collection and shipment of genetic resources. Also, the farm community or nation providing genetic resources must be able to attract users willing to pay a fee for the right to collect. That fee might either be flat or proportional to commercialization of products derived from the biological resource. The long lag-time between collection and use may limit profit sharing for funding immediate conservation programs, but up-front payments can overcome this difficulty to a certain extent (King 1991). The large number of individuals who maintain crop genetic resources greatly reduces the possibility that a single community controls sufficient resources to attract contracts. A cartel among resource producing communities is possible but dependent on government willingness to enforce limits on collection. Governments, in turn, are likely to expect a share of proceeds from the contract.

The role played by public agencies in maintaining and distributing crop germplasm weakens a market for genetic resources operating through contracts. Users of crop genetic resources usually acquire germplasm from secondary, public sources, and most of the users are themselves in the public sector. Disease control and quarantine require public agencies to be part of the genetic resource supply chain. Efficiencies in storage and screening complement these reasons for the role of public agencies. Because most of the costs of new product development using genetic resources are borne in the laboratory, collectors and users of genetic resources are apt to be more interested in contracts if they guarantee some kind of exclusive exploration rights. Public agencies, however, are unlikely to act as brokers for or grant exclusive exploration rights to one company for a particular region or crop species. The proportion of crop germplasm that has been collected from the total pool of germplasm in landraces is estimated to be high for most crops with large commercial seed markets (Chang 1992). These estimates can be expected to depress the willingness of seed companies or breeders to underwrite costly contracts that permit access to germplasm in regions of crop diversity.

5.1.2.1. Contracts as a conservation tool

Contracts may offer a viable tool for conservation, provided that their criteria emphasize efficiency of locating genetic resources and long-term conservation rather than limiting collection. One way to connect contracts to in situ conservation is for enterprising entrepreneurs or community groups in areas of biological diversity to establish themselves as intermediaries between users of genetic resources (e.g. seed companies, national programs) and farmers. Services for identifying needed genes, scouting for resources that meet the criteria of users (e.g. specific agronomic traits), and helping to connect farmers to agronomic assessment and conservation programs might be seen as greater assets than the advantages of limiting collection or have exclusive exploration rights. This requires the contract to emphasize the benefits of access and conservation.

It was argued above that three general factors limit the potential use of conventional intellectual property mechanisms (i.e. patents, plant variety protection) as conservation tools -- breeder exemptions in intellectual property legislation, allowance for derivatives, a weak market for crop genetic resources, and high transaction costs. These same factors are likely to also affect the conservation benefit from contracts between producers and users of crop genetic resources. In addition, three other factors might limit the usefulness of contracts as conservation tools. First, contracts and conservation may have very different time frames. Contracts are usually of limited duration and often one-time payments for specific services. Conservation, on the other hand, implies a long-term commitment that will be needed after the contract has lapsed.

Second, the user, who is one party to the contract, is likely to be interested in the use of the resource rather than in its conservation. Ultimately, the user's interest in the contract is for its ability to provide useful biological material. Willingness to support the contract may wane if no funding for such material is forthcoming within the company's budget cycle. Even if useful genetic material is obtained, the contracting company may decide that it has received full benefit and no longer underwrite future contracts. Fluctuating interest by users of genetic resources may create a novel type of boom and bust cycle that has been so damaging to extractive resource areas in the past.

Third, contracts involve negotiations between several parties: users, nation state bureaucracies, non-governmental organizations, and farmers; and these parties enter negotiations with different strengths and weaknesses. These power relationships are likely to have a strong impact on the conservation outcome of the contract. The strengths of industrial countries include the large stores of germplasm in public gene banks, the ability to use genetic material from many different organisms, and human capital resources in political and legal professions. The weaknesses of less developed countries include the large number of countries and farmers who produce germplasm relative to industrial users, underfunding of agricultural research, and the lack of legal and political infrastructure. Peasant farmers in marginal areas of less developed countries are primarily responsible for producing landraces, but they will not be among the principal parties in the contract negotiation. The relationship between the contract and the act of conservation will, therefore, be an indirect one.

National agricultural programs in less developed countries may be more interested in supporting underfunded program areas with money derived from contracts than initiating in situ conservation projects. National programs share the bias toward ex situ conservation that has characterized the genetic conservation effort to date. In addition, gene banks in LDCs are usually funded at very low levels so that any new money coming into conservation programs will be drawn off to support ex situ conservation. Moreover, national programs in LDCs may have limited capacity to reach and work with farmers in marginal areas where landraces exist. Thus, the administrative layer in LDCs that will negotiate conservation contracts with outside funding sources may be an obstacle to creating a new conservation program.

5.2. General obstacles to financing conservation via the market

The preceding sections have mentioned several problems associated with intellectual property and contracts as conservation tools: problems inherent in intellectual property legislation, weak markets, high transaction costs, divergent time frames and interests, and unequal negotiating strength. Whether intellectual property regimes or contract methods are used to finance conservation, they both face four general problems. These are: (1) high transaction costs, (2) sovereignty and the political status of indigenous groups, (3) negative impacts on farmers, and (4) maintaining the flow of genetic resources and technical information to and from developed nations.

5.2.1. Transaction costs

Transaction costs are the expenses of administering a system of conservation -- legal, scientific, and bureaucratic. These costs may be hidden, for instance by companies who raise prices to consumers to pay for them. Both market and non-market compensation incur transaction costs, so an important question is whether one method has lower transaction costs. For intellectual property regimes, the primary costs are those associated with rivalry, when two groups claim ownership of the same or similar ideas or biological resources. Exclusion is costly since there can be numerous contenders for the privilege. Transaction costs are likely to rise as compensation is applied in an exclusive manner, and exclusivity is necessary in order to make compensation adequate to encourage farmers to conserve local crop varieties. Claims for exclusive rights over biological resources will be frustrated by the general lack of information about their distribution. Biologists point out that a high percentage of biological diversity is not yet catalogued, described, or understood in a geographic context (Peacock 1989). This is equally true of crop genetic resources, including landraces. For instance, we know very little about the distribution of traits of bread wheat in the Middle Eastern region of diversity. Several countries, including Turkey, Iran, Iraq, Syria, Armenia and Azerbaijan, share the pool of wheat genetic resources. If one of these countries claims exclusive rights to market wheat germplasm via intellectual property or contract, others will likely challenge or undercut it. Any effort to meet this challenge is apt to require escalating costs that neither producers nor users of genetic resources can pay. An alternative is to accept a price for germplasm that is so low that rival countries are not interested in a challenge. This strategy would keep transaction costs down, but it will also depress funding for conservation. Contractors will be wary of negotiating fees for exploration and conservation without fuller knowledge of the distribution of crop resources within a broader region of diversity. This wariness will further depress fees for conservation.

Establishing an infrastructure for marketing genetic resources via intellectual property or contracts is a prerequisite for financing conservation through the market. Less developed countries are likely to lack the legal infrastructure of intellectual property systems: patent offices and courts, judicial precedent, expert witnesses, attorneys, public and private interest groups. The costs of establishing this infrastructure may exceed the value of biological resources on the world market.

Neither the market value of crop genetic resources nor the transaction costs of marketing them are known, and there is no reason to assume that the balance will be positive. Diminishing supply of biological diversity and increased demand are likely to increase the value biological resources, though this value is speculative. For crop genetic resources, two factors suggest that the market value may be relatively small. First, the demand for germplasm appears to be substantially lower than its supply (Peeters and Galeway 1988; Marshall 1989). This situation reflects breeders' unwillingness to use unknown germplasm. Second, international agricultural research institutes report that they have gathered a high percentage of crop genetic resources for many crops (NRC 1993). Because these collected resources are in the public domain, they may provide a large enough stockpile to undermine any effort to market genetic resources or to organize a cartel for the purpose of increasing their price.

5.2.2. Sovereignty

The second obstacle confronting the right to market genetic resources concerns the status of local farming cultures and indigenous people. Throughout the history of intellectual property rights, enforcement of these rights has depended on a prominent role of the nation state. Biological diversity in agriculture is frequently linked to cultural diversity and the existence of ethnic minorities (e.g. Hernandez 1985; Brush 1992; Friis-Hansen 1994). Governments may be unwilling to recognize or enforce exclusive rights of ethnic minorities to biological resources. Alternatively, indigenous groups may be wary of turning to the state for protection. An example of this problem might be seen in the Middle East. Kurdish people in Iran, Iraq, and Turkey cultivate landraces of several crops: wheat, barley, chickpeas, lentils, and sesame (Zohary and Hopf 1988). Kurdish people move between different nation states, carrying this crop germplasm with them. Because none of these states recognize the rights of Kurds to cultural or political autonomy, there is little chance that they would protect the rights of these farmers to profit from selling access to this germplasm.

States now claim biological resources as part of their sovereignty and national patrimony, as phrased in the Convention on Biological Diversity. The national sovereignty scenario, however, may bypass the indigenous or farm group that actually produces and protects the resource. Sovereignty may preclude farmers from directly contracting with collectors of genetic resources, or otherwise dilute the economic benefit reaching farmers, thus diminishing the incentive to conserve. The history of prejudice and discrimination against indigenous peoples and ethnic minorities around the world suggests that the economic benefits from commercializing biological resources will not reach indigenous farmers who maintain them.

5.2.3. Negative impacts on farmers

Extending intellectual property to plants in fields and storehouses may pose negative consequences for farmers. The tradition of common heritage means open access by farmers as well as by geneticists, and farming communities the world over conduct open seed exchange through a wide variety of mechanisms: gifts, wages paid with seed, barter, markets (Brush 1992). Exchange of local varieties among farmers is common and advantageous for several reasons, including conservation of rare cultivars. Exchange mitigates the effect of the loss of seed, and it facilitates the diffusion of superior varieties. Overturning common heritage by establishing contracts or intellectual property may possibly disrupt or terminate open exchange among farmers. Farmers who traditionally traded local varieties might have to compete with geneticists or other industrial users to acquire traditional varieties. Large-scale farms might well be advantaged because of the likelihood of having more diversity to sell, and small-scale farms would become dependent on yet another purchased input.

The farmers of most centers of crop genetic diversity are peasants living in relatively open communities, often comprised of migrants from different cultural traditions. Should royalties be given only to persons who provided resources and information? Who can claim indigenous rights to genetic resources of wheat landraces in Anatolian villages from many cultural traditions: Turkoman, Kurdish, Circasian, Crimean, Bulgarian, Albanian? Who has legitimate rights to maize genetic resources of Mesoamerica: only native language speakers or also Spanish speakers who grow traditional maize landraces? Molecular analysis suggests that maize might have originated in a well defined region in the Rio Balsas drainage southwest of Mexico City (Doebly 1990). Modern inhabitants of Guerrero might want to claim rights over maize, but such claims would certainly be challenged by other indigenous groups in the New World. Conflicts over ownership of biological resources, once commonly shared, may fuel ethnic and regional rivalries in the same way as territorial disputes.

5.2.4. Maintaining the flow of genetic resources and technology

Another negative effect of a scheme to finance conservation through marketing genetic resources is to constrain the availability of genetic resources to non-industrial countries, including those that produce them. In a certain crude sense, countries of the South can be judged to be “gene rich” and northern countries “gene poor” (Kloppenburg and Kleinman 1988), but this characterization obscures the fact that all countries depend on “exotic” genetic resources. Non-industrial countries are particularly dependent on free access to crop germplasm for breeding purposes. The breeding programs of most non-industrial countries require the infusion of germplasm from laboratories in industrial countries or international centers, partly because they lack the domestic capacity to create breeding stock. For example, of the roughly 410,00 wheat accessions in gene banks, only 53,000 are held in gene banks in LDCs, and the remainder are in gene banks of industrial country and international centers (Plucknett et al. 1987). Access to this breeding stock is essentially free, because it is generated by public programs in industrial countries or international research centers (Ayad 1994). The fact that germplasm resources have been duplicated and distributed after collection also makes it difficult to trace the origin of germplasm or to control its diffusion.

A scheme to commoditize genetic resources for the purpose of stimulating conservation may constrain the flow of crop germplasm and agricultural technology in several ways. Non-industrial countries may lack intellectual property legislation and be unwilling to allow collection of genetic resources until this is established. The two parties in contract negotiations (industrial users and non-industrial producers) may be unable to reach satisfactory contract, thus halting collection. Industrial countries may favor countries with crop germplasm in technology transfer, thus penalizing countries that do not have genetic resources or cannot reach a satisfactory agreement.

5.3. Non-market means to finance conservation

Use of a non-market approach to in situ conservation can avoid several of the problems associated with financing conservation of genetic resource through markets with intellectual property or contracts. The essence of a non-market alternative is the establishment of a multilateral trust fund to finance conservation programs that will benefit farmers. This non-market approach retains the public good and common heritage aspects of the current status of crop genetic resources. It conforms with the most widely accepted approach for addressing environmental problems, that is treating them as public issues requiring public solutions. A non-market system requires the least amount of legal adjustment in relations within and between countries. Finally, several advantages of this approach correspond to the four general obstacles of the market approach discussed above. The non-market approach is by nature non-exclusive so that the rivalry of intellectual property and contracts will be lessened. With less rivalry, transaction costs of monitoring and enforcing exclusive markets will be dramatically reduced.

While sovereignty and the relation between the nation state and local farming cultures remains a problem under any scheme, the non-market approach can mitigate this obstacle. Multilateral organizations have played an important role in emphasizing and supporting the rights of local groups and indigenous people (Breckenridge 1992). Multilateral responsibility for crop germplasm conservation is likely to have a similar positive effect relative to the groups that produce landraces.

The non-market approach is also by nature one of open access and free exchange, so that competition between farmers for control of genetic resources will be lessened. Likewise, the free flow of germplasm and agricultural technology between regions and countries will not be negatively affected by a non-market approach.

A non-market approach that emphasizes multilateral funding for conservation faces three major tasks: (1) designing a conservation program that benefits farmers, (2) estimating the scope and overall costs of the program, and (3) determining the level and mechanisms of contribution. In addition, a non-market program must also be attentive to several obstacles particular to this form of financing conservation.

5.3.1. Designing a farmers' rights conservation program

A concept that anticipates financing in situ conservation through a multilateral trust fund is the farmers' rights program developed by the Commission on Plant Genetic Resources of the Food and Agricultural Organization (FAO) of the United Nations in 1983. Farmers' rights are defined by the FAO as rights

> ... arising from the past, present and future contributions of farmers in conserving, improving, and making available plant genetic resources, particularly those in centres of origin/diversity. These rights are vested in the International Community, as trustee for present and future generations of farmers, for the purpose of ensuring full benefits to farmers, and supporting the continuation of their contributions... (FAO 1989).

The FAO farmers' rights proposal specifically eschews a market approach, thus eliminating the need for contracts or intellectual property rights to connect producers and users of genetic resources. The FAO established a fund in 1988, but this fund has not received financial backing. No fund specifically for farmers' rights has been established.

A requirement of the FAO farmers' rights effort is to develop a plan of action, which might include a component for in situ conservation. Emphasis on equity rather than conservation as the primary rationale for farmers' rights has perhaps delayed this planning effort. To date, farmers' rights literature has emphasized past contributions of farmers in LDCs and retrospective equity, rather than future benefits or conservation equity. A shift to a future-benefit rationale that emphasizes conservation rather than compensation for past contribution would strengthen the FAO proposal.

Sections 2 and 3 above present a range of options for designing and implementing a program of in situ conservation. By definition, this approach to conservation is participatory and aimed at benefiting farmers. An important prerequisite of this program is that its multinational and national administrative components be as cost effective and inexpensive as possible, with the bulk of funds going to benefit farming communities in designated conservation areas. Designing a farmers' rights program for in situ conservation might involve three general steps: (1) creating a multilateral trust fund for funding in situ conservation, (2) establishing a technical management capacity, and (3) funding country programs through a competitive grants program.

The creation of a multilateral trust fund for farmers' rights and in situ conservation might be accomplished as part of the implementation of the United Nations Convention on Biological Diversity (CBD). The proposed International Fund of the Commission on Plant Genetic Resources at FAO is a logical vehicle for this, but its relation to the Convention on Biological Diversity must be clarified. An important factor is that in situ conservation is emphasized in the CBD. The Global Environmental Facility (GEF) of the World Bank, UNDP and UNEP is a significant window of opportunity to establish a permanent funding source for farmers' rights and in situ conservation. The GEF has already funded pilot projects for in situ conservation of wild relatives of crops in Turkey and crop landraces in Ethiopia. It is appropriate to explore the establishment of a farmers' rights trust fund as part of the GEF. If international funding for biological diversity conservation is concentrated into the GEF, it is essential that farmers' rights and in situ conservation of crop germplasm be included as high priorities in GEF.

Proposals to a farmers' rights trust fund might be presented by a variety of agencies and programs -- national agricultural research programs, regional associations, non-governmental organizations, international agricultural research programs, and coalitions of these. The scope of the program of the proposal will certainly vary by crop, country, and design. It is anticipated that most programs will contain the elements outlined in Section 3: institutional strengthening (research, training, and networking), community-based conservation programs, and incentives to farmers. The costs of a single program of in situ conservation might be on the order of U.S. $1 million to U.S. $3 million per year for a period of 5 to 10 years. The global cost could be between U.S. $35 million and U.S. $50 million per year. Upgrading ex situ conservation programs might be attached to this but should not be at the expense of in situ conservation efforts. An important task of the technical management of the farmers' rights trust fund will be to maintain this priority.

5.3.2. Scope and costs of farmers' rights

The specific costs of country programs will depend on the crop(s) and activities planned for in situ conservation. Nevertheless, it will be necessary to develop a general idea of the reasonable level of funding for specific programs and for the overall effort. The costs of in situ conservation might be seen as a portion of the overall budget for conserving crop genetic resources, now devoted almost exclusively to ex situ methods. Funding for ex situ conservation is currently inadequate, both for national and international programs (NRC 1993). The possibility of new funding under the CBD suggests that in situ conservation will not have to compete directly for funding that would otherwise go to ex situ programs.

The contribution of landraces to crop improvement and the lost production or income resulting from withholding land from improved varieties should be considered in estimating the cost of in situ conservation. Using the method of hedonic pricing, the increase of crop yields resulting from the use of different genetic resources in crop breeding programs, we may estimate the value of landraces (NRC 1993). A detailed study of the use rice landraces to Indian breeding is now available (NRC 1993), and this study suggests a high value added for landraces that have been collected and used. Rice landraces from both Indian and foreign sources are estimated to have contributed 5.6% to India's increased rice yields, with an estimated value of U.S. $75 million (NRC 1993: 316-317). Extrapolating to a worldwide level, if landraces contribute as much to other areas as they have in India, the global value added to rice yields by genetic resources from landraces can be estimated at U.S. $400 million per year (NRC 1993: 317).

The annual costs of rice germplasm conservation in gene banks is currently estimated to be U.S. $700,000 for the world collection at IRRI and U.S. $300,000 for the Indian collection (NRC 1993: 317). Thus, the economic benefit of rice genetic resources far exceeds the current costs of conservation. Fixing an annual investment for conservation of landraces at 2% of their annual contribution would thus provide U.S. $1.5 million in India and U.S. $8 million dollars worldwide. Half of this share should be adequate to fund effective farmers' rights programs for rice landraces in India and elsewhere in the region of rice diversity.

Alternatively, we might think of the cost of in situ conservation as the losses suffered by poor nations and farmers who keep lower yielding, local crops rather than switching to higher yielding, modern varieties. This rests on the potential of these nations and farmers to convert their land to modern varieties. While this potential may never be fully realized, conservation costs may be estimated as though full conversion to modern varieties were possible. In India, high yielding rice varieties added between 1.22 and 1.52% per year to rice yields between 1965 and 1984 (Herdt and Capule 1983), contributing 0.32 tons or U.S. $53 per hectare (Dalrymple 1986; Herdt and Capule 1983). By setting the yield gain of modern over local varieties in areas where local ones persist at half the gain achieved previously, we may calculate a difference of 0.16 tons per hectare, valued at U.S. $27 (NRC 1993). The cost to India of paying farmers to keep rice landraces on 2% of the rice land where they are now grown (457,000 ha) would thus be U.S. $12.3 million per year. This estimate is far above the sum arrived at through the hedonic pricing method discussed above. Moreover, this investment is calculated to impact only 457,000 ha and would affect only a fraction of farmers who now grow rice landraces. High investment in rice conservation is likely to reduce other agricultural research and conservation efforts. One conclusion from these estimates is that the cost of direct subsidies to Indian rice farmers for in situ conservation is unfeasible because it would multiply the current budget by many times and exceed the annual contribution of landraces to India's production of improved rice (NRC 1993). Another conclusion is that current budgets for conservation of rice landraces is far below both their value and the costs of new conservation programs.

A major conclusion from the preceding review and analysis is that market financing for plant genetic resource conservation is untenable. This is true whether the market is established through intellectual property rights or through contracts. Without a viable market for funding conservation activities, the international community must turn to multilateral cooperation as the primary means to provide farmers' rights through in situ conservation. Since public breeding is the largest and most important use of plant genetic resources for agriculture, then public, non-market means of funding conservation are appropriate. This is the historic and proven method for funding biological conservation, and it should be pursued in the future for farmers' rights and in situ conservation. The level of a country's contribution and mechanisms for eliciting contributions to an international fund for farmers' rights have been the objects of several papers (Barton and Christensen 1988) and reports to the FAO, (Kloppenburg 1990) and they will not be treated here.

The CBD creates an excellent opportunity and forum to highlight the importance of plant genetic resources and the special role of in situ conservation of those resources. It is possible that all crop conservation programs will be funded under a single mechanism developed in the implementation phase of the CBD. The portion of funding that goes to existing ex situ programs, to national and international programs, and to in situ conservation will not be determined for some time. The opportunity to successfully introduce in situ conservation of crop resources into the implementation process of the Convention on Biological Diversity will be enhanced by having a well defined in situ program.

The inadequate level of funding for rice is reflected in all other crop genetic resource conservation, that is, far below their contribution to the world's economy (NRC 1993). For some collections, funding is so low as to threaten their viability. The addition of in situ conservation activities onto existing budgets is, therefore, unsupportable. Additional moneys are needed both to upgrade ex situ programs and to initiate in situ conservation. As argued above, market mechanisms (intellectual property or contracts) will be insufficient to fund the necessary costs of conservation. The market will fail to generate the true value of genetic resources partly because of the availability of crop germplasm from public institutions. The principles of free access to these collections and their non-commercialization have been generally reaffirmed and should continue to guide gene bank management in the world's largest collections (NRC 1993; Keystone 1991).

The Keystone Dialogue on Plant Genetic Resources set a goal of U.S. $300 million for plant genetic resource conservation at the global level (Keystone 1991). The Keystone Dialogue calculates that U.S. $200 million is necessary to maintain 4 million accessions at U.S. $50 per accession. The current estimate of 3.5 million global accessions includes approximately 1.1 million accessions in the U. S., Japan, and international research centers of the CGIAR system, or one-third of world holdings. Under the Keystone guidelines, on-farm conservation should be funded at 6% of the total crop conservation budget. This level of funding is, however, not based on a comprehensive plan for in situ conservation, and the level may be inappropriate to a full program. Nevertheless, the Keystone budget provides us with a useful starting point.

The in situ conservation program outlined above includes on-farm conservation as one component, but also includes activities that appear elsewhere in the Keystone budget. Research, training and public information are three areas identified in the Keystone budget that are very important to in situ conservation. Given the number of people to be reached, the novelty of the research area, its interdisciplinary nature, and complementarity to ex situ programs, it is appropriate that 30% of these budget areas be devoted to in situ conservation activities. Table 1 suggests a budget for in situ conservation based on the Keystone guidelines. In situ conservation is suggested to cost roughly U.S. $44 million, or 15% of the total annual global investment in crop genetic resource conservation.

TABLE 1

Budget Areas for In situ Conservation

Activity	Keystone Percentage	Portion for In situ Conservation	Cost Estimate
On-farm Conservation	6	100	U.S. $18.0 million
Research	17	0.30	15.0 million
Training	4	0.30	3.6 million
Public Education	8	0.30	2.4 million
Total			43.8 million

The program of farmers' rights through in situ conservation as outlined above is based on the assumption that programs will be targeted at carefully designated regions and groups of farmers in a limited number of countries. Eligibility for participation should be judged both at the national and regional level. National eligibility for funding to support in situ conservation as part of a farmers' rights program might include the following criteria: (1) location in a region of crop diversity, (2) the presence of a viable national program of ex situ conservation or linkage to a regional or international ex situ program, (3) the threat of genetic erosion, and (4) participation in the international system to make germplasm accessible.

A survey of the geographic location of crop diversity suggests that approximately 40 countries would satisfy the first criterion of location in a region of diversity, exclusive of developed countries. The funding range for in situ programs suggested above was between U.S. $1 million and U.S. $3 million for 5 to 10 years per program. One purpose of providing multilateral funding is to develop the national capacity to carry on in situ conservation activities after the life of the extramural funding. The funding might decrease as this national capacity is established and obtains alternative income, for instance through green marketing or green labeling programs. If U.S. $44 million is available for in situ conservation, it would be possible to fund roughly 22 programs, or slightly over half of the countries that are eligible because of location. Alternatively, funding could be used to both initiate in situ conservation in the few countries that have viable ex situ programs and to help other countries establish links to international and regional programs. Subsequently, funding could be expanded to countries that develop the national capacity and/or linkages necessary to initiate in situ conservation. A reduction in the total figure available for in situ conservation should proportionally reduce the number of programs undertaken, not the scope of the programs. The level of investment for in situ conservation should remain constant at 15% of the total annual crop conservation budget. At current budget levels of crop conservation funding (U.S. $75 million) this would suggest that roughly U.S. $12 million per year be added to current budgets for in situ conservation. At this level, approximately six country programs could be funded. Clearly, it is necessary to increase the overall budget for plant genetic resource conservation.

6. CONCLUSION

One purpose of this paper has been to argue for the viability and importance of in situ conservation as a way to satisfy farmers' rights to recognition for their contributions to global welfare through providing crop germplasm. The world community has now accepted the idea that farmers play an important role in preserving and providing crop resources. These resources are of immense value, and their value will increase as the human population grows. The need to recognize the contributions of farming people in regions of crop diversity is best fulfilled by helping them to maintain the biological and cultural resources that they have inherited. Conservation is a way to balance the interests of farmers who produce plant genetic resources and agricultural science that uses them.

Another purpose of the report has been to propose a program for in situ conservation of crop resources. Although this concept has been quite widely discussed, few actual programs have been implemented. The critical idea here is that public programs can help farmers to continue to select and maintain crop resources. This cannot or should not be seen a program to persuade farmers against choosing modern cultivars. Rather, in situ conservation can complement technological change by focusing on portions of farming systems where local cultivars are superior to modern cultivars from crop improvement programs. Farmers around the world have already found that they can keep their local cultivars on portions of their farms while at the same time selecting modern cultivars for other parts. The key to in situ conservation is to help farmers achieve greater benefit from selecting local cultivars. This can be done through the steps outlined in this report: institutional strengthening, research, training, establishing community-based conservation programs, and developing incentives for keeping local cultivars.

The final purpose of this report has been to argue that non-market means for financing crop conservation are preferred over market means. Market mechanisms, such as intellectual property rights and contracts, are undesirable for several reasons. Existing intellectual property mechanisms are unlikely to generate revenue from landraces. The potential market of crop genetic resources is far weaker than the needs for conservation. Transaction costs are too high. Sovereignty issues will confound the market derived through intellectual property rights. Markets may well restrict the open exchange of crop varieties among farmers, and markets may limit the flow of genetic resources and technology between developed and less developed regions.

Non-market means rely on the creation of a multilateral trust fund that will support in situ conservation as a way to fulfill farmers' rights. This trust fund is anticipated in the International Undertaking on Plant Genetic Resources and in the Keystone Dialogue. The completion of the Convention on Biological Diversity presents a significant and unique opportunity to develop and find support for a multilateral trust fund for farmers' rights and to implement in situ conservation. The current level of funding for conservation for plant genetic resources is inadequate. Ex situ collections are jeopardized by an insufficient and shrinking funding base, and in situ conservation exists as an exciting possibility without implementation. Current funding for conserving crop resources is far below their contribution to the world's economy and below the level necessary to insure their availability to future generations.

An opportunity now exists to create and implement a program in situ conservation that will both recognize the contribution of the cultivators of genetic resources to the welfare of all human kind and help them to preserve their invaluable genetic and cultural resources. The true beneficiaries of a program for farmers' rights and in situ conservation will be the unprecedented numbers of people who will soon inhabit the Earth. It is essential that crop genetic resources and the evolutionary processes that create them be placed at the top of the international agenda to preserve the wealth of biological diversity.

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