

The Diversity of Plant Genetic Resources: An Economic Perspective

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PLANT GENETIC RESOURCES DIVERSITY AS A COMPONENT OF BIODIVERSITY

The diversity of life on earth is the outcome of millenia of natural evolution but, from very early on, man has extensively tampered with that natural diversity. Agriculture, after all, is nothing but the conscious elimination of a very large number of plant and animal species that would otherwise thrive on a farm, to favor a few species that the farmer wants to grow. In the last few centuries, however, man's activities have intensified to the point where large numbers of species are threatened with extinction. This concern has led to widespread discussion, finally culminating in the signing of the Biodiversity Convention during the Summit on the Environment held in Rio de Janeiro in 1993.

The Biodiversity Convention is an ambitious document covering not only all forms of life, from micro-organisms to mammals, but whole ecosystems. This approach is dictated by the fact that all life is inherently interrelated. For an understanding of some of the issues involved, however, it would be more practical in a short paper such as this to take a look at some of the key aspects of the biodiversity issue. I have, therefore, chosen to look at the diversity of plant genetic resources, since this is the area in which there is a great deal of international controversy, principally over who has control of them.

The economic perspective we bring to bear on this issue begins with the observation that conservation and destruction of plant genetic resources is the outcome of the activities of large numbers of men and women, all of whom are guided by different motives and interests. We must therefore seek to ascertain who it is that wants to conserve resource diversity and who wishes to destroy it and why. Armed with this understanding, we can then address ourselves to the question as to whether or not we can harness people's motives to maintain biodiversity for future generations.

We shall divide the following discussion into two parts, one concerning wild species and the other domesticated species. There is some overlap in the subject matter between the two, since wild relatives of domesticated species are sometimes valued because of their potential in improving the latter's performance. By and large, though, the level of concern in the two cases differs. In the case of wild species, we are interested in maintaining the diversity at species level, while in the other case we are more concerned with maintaining the diversity of the cultivars.

GENETIC RESOURCES FROM WILD PLANTS

Demand-side Considerations

Resources are valued because of their usefulness, both directly and indirectly. In this case, we say that they have "use values." There are also other reasons, moral and aesthetic, why resources may have values. Man may value the survival of other species, such as dolphins, pandas or teak trees, not because the dolphins or pandas do anything that is useful for him, but because it is considered immoral to destroy these species. In this article we will ignore this second set of values, sometimes called "non-use values," not because they are unimportant, but because if we do attribute non-use values to the survival of these animals or plants, then the case for arranging their survival rests on grounds other than economic.

Sedjo (1992) gives three reasons why people consider plant genetic resources useful:

- People value the germplasm (i.e., the material in which the genes are embodied) since it can be used to grow the plants which in turn yields use values directly, such as food, fibers, medicines, etc.
- The germplasm is itself a genetic material and can be used to generate new kinds of germplasm, by various kinds of genetic manipulation, such as is done in classical plant-breeding, and more recently by means of genetic engineering. Obviously, this use is more frequently seen with domesticated plants and will be addressed in the next section.
- The plants embody various sorts of complex chemical compounds which they use for various purposes, such as warding off or attracting insects. Some of these chemical compounds can be used directly for many purposes, such as insecticides, perfumes, and, above all, as medicines. The plants could thus generate direct use values. When wishing to utilize these compounds it is, however, often economical to analyze the chemical structures of the relevant ones and then synthesize them from other materials in the laboratory. In this way, the plants provide use value through the economically valuable information of their chemical structures.

In its first use, plant germplasm is a conventional economic good and can be bought and sold like any other. Indeed, in most agricultural communities there is an active market for seeds and other sorts of germplasm. To use the economist's jargon, the second and third uses of plant genetic resources make them "nonrival public goods." A farmer's, a plant breeder's or a drug firm's use of the genetic resources does not preclude others from using them again, provided that the first party does not do so to excess. The remaining germplasm and the information embodied in the plant is still available for others to use for breeding and scientific purposes. It is, however, this very characteristic that causes problems when trying to create an efficient system of production and exchange of plant genetic resources by means of a market mechanism, as will be seen below.

The pharmaceutical industry and increasing numbers of people outside it, recognize that plants contain countless numbers of useful substances. In fact, in one way or another, one-quarter of the medicines prescribed in North America are derived from plants (Cox and Balick 1994). Many pharmaceutical companies have mounted expeditions to search for medicines throughout the world using various techniques, including the interviewing of practitioners of traditional medicine in various parts of the world. The search procedure is becoming so systematized that it has acquired the status of a subdiscipline in Western universities, and is known either as ethnobotany or ethnopharmacology.

Generally, these traditional practitioners give freely of their knowledge. But it must be recognized that not all of these traditional practices necessarily work. Consequently, a large number of candidate plants will have to be sifted. After identifying plants that are potentially useful, a great deal of further testing will still have to be done before a marketable product is obtained. The profits, however, that may be obtained from a successful drug can be very large, especially when compared against the returns made by the traditional practitioners who were the source of the information.

As medical science is advancing all the time, there is an unending search for potentially useful plants. Consequently, the disappearance of plant species could mean that some useful drugs might never be found. Further, as traditional medicine gives way to Western medicine in many parts of the world, the knowledge that was handed down over generations may also disappear. Both of these variables could greatly increase the cost of finding new drugs. There are, therefore, very important reasons to preserve the diversity of plant genetic resources, as well as the knowledge base among practitioners of traditional medicine.

Supply-side Considerations

The existence of demand alone is not sufficient to generate supply. Conserving the diversity of wild plant life is a costly business, and the large number of species alone make it imperative that the conservation be done in situ. Besides, in many cases, knowledge about a plant's usefulness may be gained only as a result of studying it in its natural environment. For most wild tropical species, conservation of plant species would

thus automatically imply conservation of the ecosystems in which these species thrive. Such conservation efforts require the setting aside of extensive tracts of wilderness which, for many developing countries, would result in high and increasing maintenance costs. It should be pointed out though, that such wilderness areas have uses other than mere conservation of biodiversity, such as the prevention of soil erosion. Consequently, not all the costs of the land need to be charged against conservation efforts.

Mere conservation of biodiversity without knowledge of what it is that is being conserved would, of course, be quite useless. It is essential that conservation efforts be accompanied by extensive surveys and the placing on an adequate database all the species within the conservation area.

Private firms or individuals are clearly not in any way attracted to invest in efforts to conserve plant genetic resource diversity, even though some of the resources obtained may sometimes yield large profits. Without adequate institutions, the "public goods" nature of plant genetic resource diversity precludes such investments. We now turn to the question as to whether or not such institutions can be devised.

Can We Create a Market to Make Beneficiaries of Plant Resource Diversity Pay for the Costs?

Creating a market in plant resource diversity entails the creation of clear property rights over the resources concerned. Since, for wild plant genetic resources, the true generator of use values is not necessarily the material itself, but the information contained in it, the property rights do not reside in the material, but in the information. Since extracting information from the material is itself costly, and need not be done by the property owner, this raises issues of some complexity. Perhaps the best approach to an understanding of these issues is to look at the famous contract made between Merck, an American pharmaceutical firm and the National Biodiversity Institute (INBio), a nonprofit institute in Costa Rica, signed in 1991 (see Reid et al. 1993 for further details).

In that contract, INBio was hired by Merck to gather and classify specimens of various species of plants and insects for a sum of one million US dollars. These plant specimens cannot be shared with any other pharmaceutical firm, but Costa Rican law requires that INBio shares the specimens with the Wildlife Department of the Costa Rican government. If materials extracted from any of the specimens are incorporated into drugs sold by Merck, then the latter will pay a royalty (the exact amount or proportion is not specified in the contract) to INBio. Additionally, Merck is committed in providing assistance in equipping INBio's laboratory and in training INBio workers in assaying methods.

This particular transaction must be considered against the background of Costa Rican law. That requires any collector of plant, animal or microorganism specimens, whether a foreigner or a Costa Rican national, to obtain permission from the government's Wildlife Department, and submit a detailed work plan. If the collector is a foreigner, then the collector must be qualified to do so. When the collection is complete, the Wildlife Department requires the collector to deposit duplicates at the Wildlife Department and to leave the research report arising out of the collection with the Department or the National Library.

This legal framework is necessary but insufficient to protect Costa Rican interests. The establishment of INBio is the next essential step. INBio has developed a program of work that will establish its own capability in plant taxonomy and bioassay methods. The agreement with Merck is but a step in that direction. Ultimately it aims to develop a database of all plant and insect species found in Costa Rica.

From the economist's point of view, the legal framework establishes the fact that genetic resources within Costa Rica are government property, and permission has to be obtained from the government to explore them. INBio acts as a transactor in the market for the actual resources, not only as a concessionaire from the government, but also as a concessionaire who has the potential to develop Costa Rican capability in the area.

Such a framework is fully consonant with the Biodiversity Convention, although it is worth pointing out that the agreement was signed prior to the signing of the Convention. Costa Rica, as a sovereign state, has the right to restrict its own citizens' and foreigners' activities in the country so long as these restrictions do not

conflict with any international agreements. Prior to the Convention, there was nothing, except perhaps the FAO (Food and Agriculture Organization of the United Nations) Undertaking on Plant Genetic Resources (which does not have the force of law) to restrict Costa Rican freedom of action in this area. The Convention merely emphasizes this freedom of action.

The lessons that may be drawn from this experiment (it is too early to call it an experience) are:

- Private companies that benefit from a country's genetic resources should be made to pay for the cost of maintaining them.
- To induce them to do so, a country's domestic laws and regulations must clearly establish rights and responsibilities.
- The amount that can be expected from such exercises, at least in the early stages, cannot be expected to be large, certainly not large enough to pay for the full cost of maintaining the biodiversity in a country.
- To maximize the benefits accruing to the country, it must be willing to expend efforts at building up its own scientific capability.

GENETIC RESOURCES FROM DOMESTICATED PLANTS

Suppliers of Domesticated Plant Genetic Resources

From the very beginning of agriculture, the chief maintainers of genetic diversity among domesticated plants have been the farmers themselves. Over millenia farmers have selected the seeds of those plants that are best adapted to the specific environment that they face. In some cases, a farmer would select many cultivars for strategic reasons. He may, for example, wish to minimize the risks of attacks from pests and diseases—it is well known that a genetically non-uniform field of plants would resist such attacks better than a uniform one. He may also plant many varieties to reduce peak labor demands. Thai rice farmers used to plant as many as three different cultivars that matured at different times, so as to spread the harvesting season over a longer period. Indeed, in many farming systems, not only are there many cultivars, there are many species grown as well.

As farming of each crop has spread over the globe, farmers in different regions have selected different cultivars to grow in their localities. As one moves away from the center of origin of that species, the number of cultivars tends to decline. It is this simple observation that underlies Vavilov's great work on the domestication of plants.

It must, therefore, be recognized that unless there is a conscious effort on the part of the farmers themselves to grow many cultivars simultaneously, farming generally entails a reduction in the diversity of cultivars that are grown in any locality. Indeed, for the vegetatively propagated crops, the number of cultivars grown is normally quite small. Thus, Evenson and Kisslev (1975:34-5) indicated that from the sixth to the eighteenth century, prior to the advent of modern genetic improvement methods, only one variety of cane was grown throughout the world.

In recent years, however, this natural tendency has been further encouraged by the germplasm improvements that are taking place in the various crop research centers around the globe. These improvements have led to yield increases so decisive that farmers have stopped growing many traditional cultivars in favour of modern ones.

This shift gives rise to two possible problems: genetic uniformity and genetic erosion. It is feared that the increase in genetic uniformity will expose the farmers to more severe attacks from pests and diseases, such as the case of the outbreak of the Southern leaf blight disease in the United States in 1970. This attack was attributed to the use of the same male sterile line as the female parent of all the hybrids distributed in the U.S. A similar attack was reported on rice in Indonesia in the mid-1970s. The analysis in Anderson and Hazell (1989), however, indicates that the overall gain from the improvements in yield are so large as to outweigh the increased risks.

More germane to the subject matter of this paper is the problem of genetic erosion. With farmers abandoning traditional cultivars in favour of modern cultivars, there needs to be some means of conserving the genetic resources embodied in the former. The more favoured practice, because it is vastly more cost-effective, is to store these resources *ex situ* in gene banks or, in the case of tree crops, in botanical gardens or arboreta. For the major domesticated plants, including all the major cereals, there is now in storage an almost complete collection of the seeds of most of the cultivars that are extant in the world (Plucknett et al. 1987). For many locally grown and consumed plants, such as fruit and vegetables, however, the situation is far from satisfactory. For developing countries, the establishment of gene banks for these species should be a priority.

More recently, voices have been heard calling for farmers themselves to become involved in conserving genetic resources. Altieri and Merrick (1987) have suggested that a strategy of conserving on-farm genetic resource diversity be 'built in' to development projects directed at small and poor farmers. While at the moment this approach may be justified in terms of improving the welfare of farmers in a given locality, as their community develops the farmers' strategy in dealing with maintenance of genetic resource diversity may also evolve away from the strategy that they are currently adopting. There is very little to assure the rest of the world that the existing genetic resources will be maintained.

Once again, it has to be noted that it is costly to maintain crop genetic resource diversity. *In situ* conservation, if it implies that farmers have to accept a lower standard of living than what they would get from growing improved cultivars, is certainly a costly means of achieving that objective. It has to be admitted that *in situ* conservation also has certain benefits to the rest of the world which are not conferred by *ex situ* methods. That is to say it permits the evolution of plants in natural conditions, and it allows scientists to study the strength and vulnerability of each cultivar in its natural environment.

It is interesting that gene banks are mostly part of publicly-funded institutions. If it is thought that farmers are conferring public benefits by their conservation activities, then there is some justification in subsidizing them, although designing such a subsidy program would be quite problematic.

In discussing the supply side, we cannot close without mentioning a fact that is often overlooked, namely that the activities of modern plant breeders also contribute to the diversity of cultivars available to farmers. By recombining the genes in novel ways, plant breeders have introduced new cultivars into the world. Modern biotechnology promises to bring even more radical transformations in the cultivars available. Again, such expansion is costly and has to be paid for. We shall return to this issue in the last part of this section.

Demanders of Diversity in Domesticated Plant Genetic Resources

Plant breeders are usually cast as the villains for their role in making farmers abandon their traditional cultivars, thus leading to the problem of genetic erosion. It is an ironic fact of modern agriculture that the people who most keenly feel the loss of the diversity of genetic resources of the domesticated plants are the plant-breeders, because this loss makes their task much more difficult. It is not coincidental, therefore, that most institutions that house the gene banks are places where plant breeders have a major role.

Plant breeders demand genetic resource diversity because their work produces economic value. This value arises from the higher yields that their work makes possible. For them to be able to pay for conserving the diversity of genetic resources, they must be paid for the work that they do. The work that they do, however, is embodied in the improved seeds or germplasm that is the end-product of their work. Since this material is freely reproducible, it is not possible for them to recapture the work they put into it. The case of hybrid seeds where farmers have to come back to buy the seeds being the exception.

Thus, in most advanced countries over the past one hundred years, the overwhelming amount of plant breeding work has been conducted in, or funded by, public institutions. As modern biotechnological methods expand the scope of their and other scientists' work, the financing of future research will change. Private firms are increasingly involved in plant genetic improvements. Since they are pouring resources into this activity, they are demanding that the government give them intellectual property protection over the

results of their investments.

If private firms modify plants using the genetic resources that are now currently freely available from public institutions, can they be made to pay for the conservation of those resources? More importantly, if those genetic resources arise from another country, can that country, or farmers of that country, claim some payment for the use of their material?

There are two approaches to answering these questions: one is to tackle them as questions of fairness and the other is to tackle them as questions of incentives. I do not have the competence to pronounce on the fairness of the existing or newly contemplated arrangements. In this paper, I shall only deal with the question of incentives: whether the existing arrangement induces various parties to conserve *and use* plant genetic resources in ways that will enhance the welfare of the farmers around the world. To address this question, we have to tackle the issue of intellectual property rights over plant genetic resources.

Intellectual Property Rights over Plant Genetic Resources

Currently two forms of intellectual property rights protection exist in developed countries for plant genetic resources: plant variety protection and patents. The first is designed to protect the rights of plant breeders who use classical methods of crossing and selection. To be protected, the plant breeder must be able to show that the cultivar developed is:

- distinct from other cultivars which have been hitherto available
- uniform
- stable

Patents are more suited to biotechnologically developed products. To be able to secure a patent, the applicant must show that the product or process possesses the following properties:

- utility—the product or process must actually be useful to someone
- novel—the product or process must not be something that was previously available
- there must be a nonobvious step from other discoveries

It is the last step that makes a patent the more significant instrument. It makes patents more difficult to obtain, but by the same token, once obtained, it provides the holder with greater protection against competition. One more feature of patents needs to be mentioned. The process and product must be described in the patent application which will be open for public inspection.

A third form of protection, not strictly intellectual property protection, ought to be mentioned in this context, namely, trade secrets—a subject which in many countries is covered by law. Producers of hybrid seeds rely mostly on this form of protection in preference to either of the other two forms.

Do these forms of intellectual property protection provide sufficient incentives for private firms or individuals to engage in genetic improvement work? Empirical findings in this area are meager, particularly on patents which are, as far as plants are concerned, fairly recent phenomena (Lesser 1991). By and large, the findings indicate that intellectual property protection does not lead to a great deal more improved cultivars, but that once protection is given, it does not significantly increase the price of seeds to the farmer. One study in the U.S. indicates that holders of plant variety protection are able to get back from the farmers 25 to 50 percent of the yield gains (Lesser 1991: 36).

These are incentives for firms to engage in genetic improvements. There is no incentive for them to conserve existing genetic resources. Under present circumstances, with public institutions undertaking this task and making the material freely available to users, there is little incentive for them to do so. But since these firms are able to recover the costs of their research because of intellectual property protection, gene banks and others who attempt to conserve genetic resources should be able to recoup their costs. By the same token, developing countries from which the genetic resources are taken should share in these

benefits. Here, a point needs to be made—most of the genetic resources from developing countries are already deposited in public institutions. There should be an attempt to enhance the collection, particularly of those species for which there is no adequate collection. Charging plant breeders or private firms for use of these new materials could provide the incentive to expand the coverage of gene banks.

CONCLUSIONS

- The first priority of all developing countries should be to conserve plant genetic resources, both wild and domesticated.
- Use of public funds for this purpose seems inescapable, although there are ways in which *part* of the costs may be recovered.
- The impact of intellectual property protection on small, developing countries would be quite small.
- The Biodiversity Convention merely emphasized the rights to control the acquisition of the plant genetic resources within the developing countries—something which they already had.
- To regulate foreigners' use of a country's genetic resources, there must be an adequate legal and institutional framework.

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