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PART TWO: Industry Issues

10. A Market for Genetically Coded Information as an Efficient Exchange Mechanism for Genetic Resources? Some Conceptual Considerations

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Chapter 10

A Market for Genetically Coded Information as an Efficient Exchange Mechanism for Genetic Resources? Some Conceptual Considerations.

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Introduction

One of the biggest challenges facing the world today is keeping up with the increasing food demand due to population growth and the increase of the average purchasing power. Aside from the sustainable management of soil and water, the sustainable management of genetic resources is one of the three indispensable preconditions for a sustainable agriculture in the future. In this context, genetic resources are essential inputs for the biotechnology in general and are necessary for the breeding efforts to solve the future challenges in particular.

As demand for genetic resources increases because of new technology and new applications of biotechnology the genetic diversity is reduced. The decline of genetic resources is caused through the displacement of traditional by modern varieties and introduced crops in farmers' fields as well as the reduction of forest area and other areas important for the general biodiversity.

The importance of plant genetic resources for food and agriculture derived from local varieties or from wild relatives of domesticated crops has not been reflected economically. The free and unlimited availability of plant genetic resources has been taken for granted and the small but important input of traditional varieties or wild crop relatives was often neglected in breeding programs. Given the changes in demand and supply and the institutional rearrangements, breeding as an essential precondition for food-production will require a more intensive and intelligent utilization of genetic resources in the future.

Lacking estimations on the value of genetic resources for global welfare (e.g., value for breeding) and the costs of conservation, investments in genetic resources conservation are most likely sub-optimal at the margin. These deficits of information and uncertainties are hindering an economically efficient approach to optimizing agrobiodiversity conservation. Additionally, allocative problems such as the imbalance between the shared costs and the benefits of conservation hamper an optimal conservation at all levels. For example, some countries with a high amount of unique genetic resources belong to the poorest countries in the world, where investment in conservation is constrained by very limited resources and other priorities for the use of available funds (von Braun and Virchow 1997).

Consequently, there is a threat for an optimal supply of genetic resources. Considering these circumstances, there is a need for exchange mechanisms, which indicate the existing needs for genetic resources, as well as the insurance that incentives are adequate for those maintaining genetic resources.

This study wants to contribute to the development and the conceptualizing of more efficient exchange strategies by discussing the existing and potential exchange mechanisms for genetic resources and to compare their efficiency in the light of a secure long-term conservation.

Biodiversity's Metamorphosis to Genetically Coded Information

Biodiversity is defined in quite different ways. Consequently, the estimation and valuation of diversity depends on the definition used. In general, the term biodiversity has no operational value for analyzing, valuing, and devising efficient conservation and exchange options on the basis of economic instruments. This applies as well to the term agrobiodiversity defined broadly as *"... that part of biodiversity which nurtures people and which are nurtured by people ..."* (FAO 1995a, paragraph 67). Plant genetic resources for food and agriculture (PGRFA) is the general expression for the material growing in farmers' fields and their wild crop relatives, as well as material which is conserved, exchanged and utilized. The terminology of "plant genetic resources for food and agriculture" does not, however, permit applications of economic concepts to the problems of scarcity, conservation and transaction.

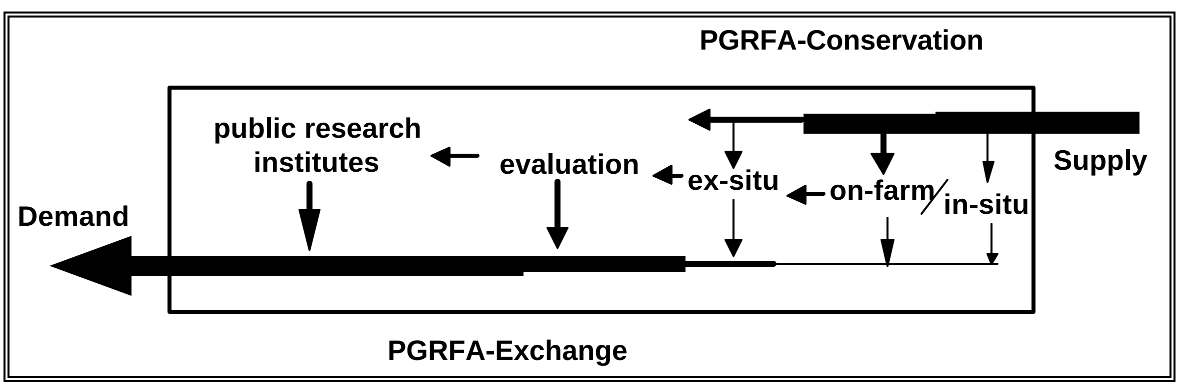
The conservators of PGRFA (the major actors of the supply side of PGRFA) tend to favor the use of qualitative traits as marker genes to monitor the extent of diversity. Often not agronomically relevant but frequently genetically linked to agronomic traits, these traits are mostly components of the characterization data, giving information on color, morphology or enzyme variants of accessions. The major actors on the demand side of PGRFA (the breeders and the biotechnology industry in general) are, however, more interested in quantitative traits, including agronomic traits such as yield capacity or plant height. These quantitative traits, which define the breeding goals, are lastly functions of certain biological organisms. Often these traits are not due to single genes but rather to a combination of genes representing one required function. For this reason (Vogel 1994) argues in favor of using the term "genetically coded function" (GCF) as a basis for economic valuation of genetic resources exchange mechanisms. Although this seems correct, GCF is determined by specific combinations of genetically coded information (GCI). Finally, the actors (especially the biotechnology industry) demand information, which determines certain functions. As technologies improve, one objective will be the virtual construction and reproduction of genetic basis (e.g., production of amino-acid sequences). Consequently, in light of the emerging market, and the articulation of the demand side, genetically coded information is recommended here as the unit, which can be utilized for economic and - in the long run - institutional analysis, discussion and negotiations of PGRFA. Genetically coded information will be the unit that will enable the development of appropriate concepts for identifying alternative institutional mechanisms for the protection, transaction, and utilization of genetic resources within the framework of general concepts of nature conservation, including the formation of markets.

Another advantage of genetically coded information, as an economic unit is the opportunity to have a comprehensive unit which is applicable to genetic resources exchange and transaction systems in agriculture as well as to the transaction of genetic resources in general. As a future consequence, the institutional framework of conservation of genetic resources will be challenged by an emerging information market.

The Market for Genetic Resources: Demand and Supply of Genetically Coded Information

At the moment, the diffusion of genetic resources from supply to demand underlies a complex structure, determined by the different steps of information processing (see FIGURE 1). PGRFA are "offered" as wild relatives of the crop species in situ, as traditional varieties on-farm or as PGRFA accessions in the various steps of processing ex situ. The accessions in the conservation facilities are on the one hand just maintained without any characterization work done. On the other hand, genetic resources are characterized, evaluated and even pre-bred in public research institutes, increasing their value by adding additional information. Consequently, the demand side is mostly interested in the processed accessions but is also willing to receive accessions with low or no additional information added, if necessary.

FIGURE 1 PGRFA's Diffusion from Supply to Demand



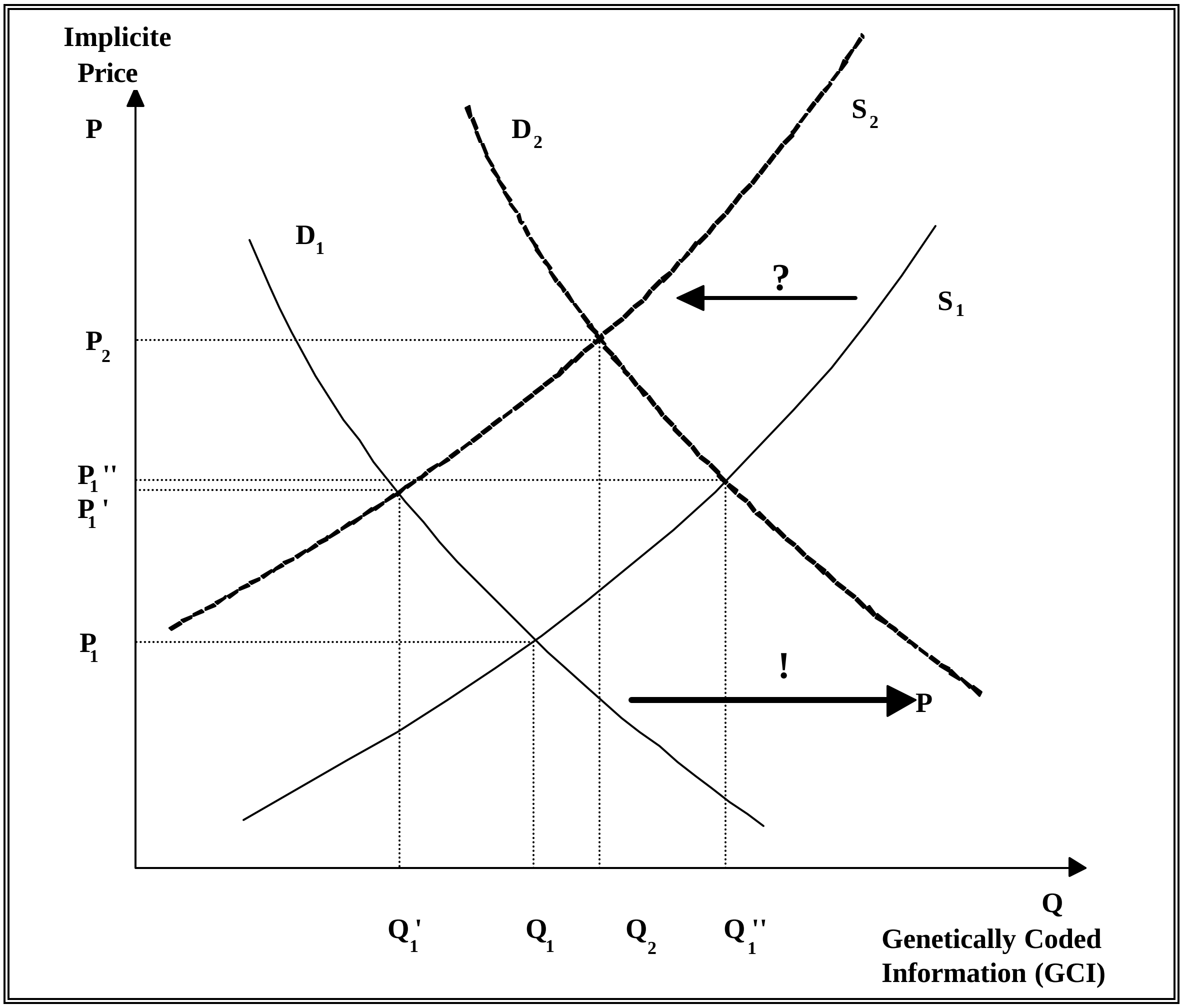
The supply of genetic resources comes from gene banks and other ex situ collections and from their natural places of origin (in situ). On the one hand, the in situ supply of genetic resources is subject to processes of physical decline (erosion of biodiversity). On the other hand, the technologies for exploring and identifying genetic resources (bioprospecting) are developing rapidly thus are lowering the marginal costs of rendering these resources marketable.

Genetic resources are in decline in terms of cultivable plant species and their wild relatives. There is neither information on historical situation as regards agrobiodiversity, nor a comprehensive inventory of what currently exists in farmers' fields. As an indicator for the loss of varietal diversity, cultivar replacement measured by area is quoted in some literature. Nevertheless, genetic extinction in agriculture is poorly documented. Until now, genetic extinction occurs mainly in the form of the replacement of traditional varieties in main production areas, where genetic uniformity is increasing instead. Because the process of concentration of diversity occurs in smaller areas than in the past the last resort for the majority of traditional varieties are the ecological marginal areas. In India, for example, 75% of an area which once accommodated up to 30,0000 rice varieties are now taken up by only 10 (FAO 1993a). This is compensated for to some extent by the fact that today's improved varieties contain considerable amounts of genetic material derived from traditional varieties, which incidentally explains their favorable yield at many sites. It must be stressed here that while plant diversity is indisputably in decline, our knowledge of the existing diversity worldwide is still very rudimentary. Complete uncertainty remains as to the extent to which loss of diversity also means loss of genetic resources. In addition to PGRFA, there is an enormous genetic and biochemical diversity worldwide, e.g., among worms and soil microorganisms.

Besides the supply of genetic resources in situ, there is an enormous stock of PGRFA ex situ. The conservation of PGRFA is a complex international and national system, consisting of 6.2 million accessions of 80 different crops, stored in 1,320 genebanks and related facilities in 131 countries (FAO 1998). Hammer (1995) points out, however, that the vulnerability of resources stored in gene banks due to the dependence of these institutions on governmental systems has become more evident in recent times. This has been demonstrated, for example, by the changes taking place in the former Soviet Union and other East Block states, which led to the break-up of the traditional Vavilov Institute with its once widely branching network of stations. Local collections such as those in Somalia and Rwanda have also recently been subject to destruction problems. These developments have stimulated international initiatives for the duplication of material stored in gene banks.

Principally speaking, scarcity of biodiversity leads to a leftward shift of the supply curve for genetically coded information (from S_1 to S_2 in FIGURE 2), or at least to an expectancy of such a shift, and consequently to a rise in prices (from P_1 to $P_1{}'$). At the same time, however, improved information processing in the ex situ facilities and technological innovation in the identification of genetically coded information has a downward effect on the marginal costs of making them available. These costs have fallen rapidly in recent years (Artuso 1994). New chemical and analytical methods have rapidly enhanced the efficiency with which natural products can be identified and selected (e.g., new developments in chromatography and spectrometry). Hence, as Tanksley puts it: "*Maintaining but not using seed banks was like having this huge bank account in Switzerland, but nobody had given us the password, so* *we couldn't trap into it. The genes ... are sitting there, waiting to be used. And now maybe we can start using them...*" (Tanksley 1997). Thus, the GCI supply curve's leftward shift resulting from erosion tendencies is partly compensated for (FIGURE 2), and the (implicit) price increase in the GCI market turns out smaller than one might expect.

FIGURE 2 Changes in Supply of and Demand for Genetically Coded Information



Source: von Braun and Virchow 1997.

However, technological advances in the identification of GCI also exert an influence on the (derived) demand for genetic resources. They act simultaneously with other technologies enhancing the demand for GCI. As explained above, the trend towards scarcity on the supply side of the GCI market is some what obscured by the present technical advances in information processing and "bioprospecting". By contrast, the demand for GCI deriving from the biotechnology industry is quite obviously expanding (D_1 to D_2 in Figure 2). Through the accumulation of knowledge the development of biotechnology has taken on an exponential dynamic. Genetic engineering, in particular, and new applications in biotechnology appear to have pushed the limits to innovation further. In agriculture particularly the genetic information contained in the world's major useful plants will probably become more important, as they are relatively easy to manipulate by breeding with the existing technological know-how. Still virtually inexistent ten years ago, genetic modification of plants has meanwhile progressed to various stages (Plucknett et al. 1990; OECD 1992; FAO 1993b; de Kathen 1996).

At present one can only speculate on the future economic demand for biodiversity and GCI. This is an inevitable ingredient to any economic process undergoing rapid change just as it is now to the formation of GCI markets. As the possibilities of biotechnology improve, stimulating the demand for diverse genetic resources, so will genetic resources rise in value. For instance, the German gene bank of Gatersleben alone receives some 13,000 requests for seed samples for breeding and research purposes every year (Hammer 1995).

In the long term the further technological improvements will facilitate the incorporation of alien plant genes into useful plants. This will lessen the attraction of traditional varieties and their wild relatives for breeding. New, improved methods of biotechnology will lead to a gradual characterization (and conservation) of more and more genetic resources, and, through the reproduction of existing and design of new genes, to the establishment of a virtual genetic base (e.g., preparation of amino acid sequences) and combination of genetic information. In the long term this could curb the demand for genetic resources as a raw material for genetic information, particularly if in vitro reproduction of genetic information becomes cheaper than in situ or ex situ conservation of genetic resources. This in turn could lead to the substitution of biotechnologically (in vitro) duplicated genes for natural genes and agents. However, as long as the in situ and ex situ conservation of genetic resources are still the more cost-effective methods, and assessments of the efficacy of substitutes speculative, substitution will remain confined to a few specific products (Virchow 1999).

Institutional Aspects of Exchange of PGRFA: The Long and Winding Road from a Free to a Private Good

Before CBD came into force in 1993, the instruments for the institutional framework of PGRFA conservation management, germplasm exchange and utilization were developed in a rather ad hoc manner, based mainly on national and international codex for research work. The achievement of having identified or discovered a variety in farmers' fields with interesting traits was credited through publications and other kind of awards; but the farmers who bred and maintained that variety in their fields were seldom mentioned. Germplasm exchange was regulated according to other natural resources transfer in research, i.e., free to all bona fide users and based on "pro mutua communatione", the mutual exchange like it is practiced between botanical gardens as well (Hammer 1995). Engaged in the conservation and utilization of PGRFA since its beginning, FAO developed some instruments, which are now integrated into FAO's *Global System for the Conservation and Utilization of Plant Genetic Resources* *for Food and Agriculture* (FAO 1997). This global system was the formal framework for the access and exchange of PGRFA since the adoption of the International Undertaking on Plant Genetic Resources, based on the Undertaking's basic concept of a multilateral system.

Since the enforcement of CBD in 1993, however, the international exchange system for PGRFA has undergone some drawbacks. Because of its revision the framework given by the International Undertaking is not existent at present. Nevertheless, CBD provides for access to be granted on "mutually agreed terms", which might be agreed upon bilaterally or multilaterally (UNEP 1994). The current multilateral exchange system is generally conducted without a formal agreement. Hence, its informality and uncertainty characterize the existing exchange system. Nevertheless, most countries state that PGRFA in national collections are still freely available to all bona fide users. But in some Eastern European countries, the recent privatization of agricultural research institutes has increased the uncertainty over the continuing free availability of their PGRFA (FAO 1998). Furthermore, there are signs that the access to PGRFA in countries of supply is starting to be restricted, e.g., the Chinese genebank is restricting the exchange of indigenous germplasm (FAO 1998). Some other countries might restrict the access by establishing bureaucratic obstacles (Hammer 1995).

So far, as a rule no price is charged for the utilization of PGRFA through breeders. Furthermore, hardly any remuneration is offered, neither to farmers, who are maintaining PGRFA diversity in their fields, nor to the ex situ conservators, who are maintaining the genetic resources and are involved in the first processing of genetically coded information derived from PGRFA (see Chapter 0).

The uncontrolled reduction of area under traditional varieties due to technical and economic development call for an exchange system, which is efficient and provides sufficient incentives for maintaining genetic resources. Furthermore the lack of sufficient resources for incentives at a national level, and the insecurity of additional funds on the international level are stressing the need for an efficient exchange system. The central policy questions concerning PGRFA presently being discussed at the different international fora are (Virchow 1999):

- the national sovereignty over PGRFA;
- the setup of some kind of property rights associated with genetic resources and its enforcement;
- the arrangement for the access to PGRFA;
- the sharing of benefits of PGRFA between "owners" and users;
- the aspects of financing conservation and the supply of genetic resources.

A conservation and exchange system must solve these problems and integrate all of these issues. Progress has been delayed, because these issues are interrelated, and the main actors in negotiation have contrary objectives. KLOPPENBURG and KLEINMAN (1988) identified the declaration of the property rights as the major reason in the deadlock of the discussions ten years ago. The industrialized countries recommend that genetic resources derived from traditional varieties be treated as common heritage but modern varieties have to be protected. The developing countries would also like to declare the newly bred varieties of the seed industry as public good or to protect the traditional varieties as well.

As suppliers of genetically coded information or of the raw material for such information, i.e., germplasm, agrobiodiversity rich countries are in need for newly developed seed and are therefore interested in its technology. This technology is supplied by countries, which are mainly characterized as diversity poor. Consequently, each side has negotiation resources which are of interest to the other side and the solutions should be feasible (Svarstad 1994). The negotiation resources, however, are not equally distributed at present, because the industrialized countries (defined as OECD countries for this purpose) have approximately 40% of all conserved accessions at their disposal (FAO 1998). Additionally, the accessions of the CGIAR centers are also available for all users. This situation strengthens the negotiation position of the industrialized countries. The exclusion of conserved germplasm collected before the adoption of CBD may serve as an indication for the importance of this fact.

It is, however, not only a dispute between the industrialized countries as agrobiodiversity poor countries and the developing countries as agrobiodiversity rich countries, but rather a debate between the suppliers themselves. On the one side the supply of and demand for political lobbying for internalization of the benefits derived from the utilization of PGRFA are determined by existing or expected market power of some countries through property rights solutions, while the prospects of compensation solutions trigger rent-seeking initiatives on the other side (von Braun and Virchow 1997). Hence, the discussion over the best exchange system is not only driven by the search for the most efficient solution, but also fuelled by country specific interests (see Chapter 0).

Furthermore, the system of conservation and exchange of PGRFA that must be created is influenced by other international and national negotiations, treaties, and laws. For instance, UPOV and TRIPS/WTO representing international agreements on the demand side of genetic resources and CBD and the International Undertaking representing the major agreements on the supply side of PGRFA. The network of national and international agreements complicates the negotiations and the potential solutions (Virchow 1999).

Markets and other exchange mechanism cannot evolve without any international and national framework; or they only may evolve into an informal system without any long-term planning and investment potential. Missing markets and the deficit of other regulation mechanisms are, however, a threat for the conservation and allocation of PGRFA. Hence, markets for the exchange of genetic resources, as part of the internalization mechanism, as well as other regulations to compensate farmers and countries for maintaining a specific level of agrobiodiversity have to be developed.

Exchange Mechanisms:
Different Ways for Genetically Coded Information to Reach the Demand Side

There is presently a wide spectrum of genetic resources exchange systems in discussion: at one side there is the informal multilateral approach, which does not reflect all of the legal binding points addressed in CBD; at the other end a strictly bilateral exchange system can be identified. Meanwhile partial elements of markets for genetic resources are emerging in the field of pharmaceuticals, as can be seen in contractual agreements between gene owner countries and gene users (either countries or the pharmaceutical industry in industrialized countries).

This leads to questions as to which arrangements for marketable components of genetically coded information might be practicable in agriculture and how to create incentives for securing genetic resources that are not yet marketable. Including the issue of the utilization's benefit sharing as well as the conservation's burden sharing, the future exchange system of PGRFA will determine the incentives for PGRFA conservation to a major extent. Only if the countries, hosting predominant parts of PGRFA, can anticipate a significant compensation for the costs of conservation, they will be prepared to invest in PGRFA conservation in the future as well.

The exchange of PGRFA presently takes place in a complex multilateral system that is based on legally non-binding and informal agreements, some of which were only accepted by tradition. The core element of the existing system is the unrestricted and free availability of PGRFA to all bona fide users worldwide. This policy, which is followed by all major ex situ collection facilities, was based on the general assumption that genetic resources were a *"common heritage of mankind"* and a *"common concern of humankind"* (UNEP 1994) and consequently a public good. Because of the free availability and determined by the concern of saving all threatened genetic resources, the conservation efforts were carried out in a very unsystematic way, determined mainly by the individual commitment of those involved. Furthermore, in the present multilateral system most countries share part of a total genepool of interest for most staple food crops and the governments have exercised little control over the exchange of germplasm in this informal system (Gass 1996).

FAO and the IARCs combined with the NARS tried to systemize and link all conservation efforts on international and national level. Consequently, the main coordinators of the existing system in its present state are the "Global System for the Conservation and Utilization of PGRFA" and the network of genetic resource units and plant breeding activities, promoted and financial supported by the IARCs and the relevant NARS.

The global system consists of three pillars, based on the International Undertaking as framework agreement and is accountable to the intergovernmental forum of the Commission of Genetic Resources for Food and Agriculture (FAO 1997):

- global mechanisms: an international network of ex situ collections under the auspices of FAO, a network of in situ and on-farm areas, crop related networks, and the World Information and Early Warning System on Plant Genetic Resources (WIEWS);
- global instruments: the international fund on Plant Genetic Resources for the implementation of Farmers' Rights, a periodic report on the State of World's Plant Genetic Resources, and a rolling Global Plan of Action on PGRFA;
- international agreements: an international code of conduct for plant germplasm collecting and transfer, a draft code of conduct for biotechnology, technical guidelines for the safe movement of Plant Germplasm, as well as the genebank standards.

The achievements of this system, whose legal framework is still evolving, because of the obligation of renegotiating the International Undertaking, are the following:

- most of the earth's important PGRFA have been collected and conserved ex situ under this evolving, informal system (WIEWS 1996);
- genetic resources have been utilized for breeding and provided the base for a tremendous food production increase (Wright 1998);
- the system provided the fora for international negotiations on policies and regulations on PGRFA and enabled the emergence of the first report on the state of the world's PGRFA as well as the first global plan of action for the conservation and utilization of PGRFA (FAO 1998; FAO 1996a);
- the first international PGRFA information system was created (WIEWS 1996) crop-specific and regional PGRFA networks emerged for cooperation reasons (Anishetty and Virchow 1999);
- the present exchange system with its free availability of PGRFA to bona fide users upon request enabled the advantageous utilization of more PGRFA from international sources than contributed to other national and international users because of the interdependence of all countries as regards the utilization of PGRFA (FAO 1998).

Although some major points of conservation and utilization of PGRFA have been achieved with the existing system, there are still some major elements missing. Main missing elements are the acceptance and implementation of specific financing mechanisms for benefit and burden sharing and the adoption of a revised International Undertaking including the recognition of the Farmers' Rights.

A multilateral system for controlling the exchange of PGRFA should have the task of providing suitable incentives for in situ conservation and ensuring a fair share of the benefits of the utilization of these resources to the donor countries. It should also facilitate access to plant genetic resources necessary for agricultural products and provide mechanisms for the regulation of this access where necessary, e.g., when requirements of nature conservation take precedence over other concerns. Such a system must also answer to basic institutional principles such as the equal access for the national agricultural research systems of all countries, the transparency of decision-making processes, the control of executive organs, and the securing of finances (Cooper et al. 1994).

The principle of a bilateral agreement for the exchange of PGRFA is characterized by the negotiations between two countries and is formalized through a contract. It can be restricted to a single exchange of germplasm between two countries, e.g., the bilateral agreement between Brazil and Malaysia for the exchange of a specific quantity of wild material of Hevea for a specific quantity of elite clones for other Hevea varieties (IPGRI 1996). The bilateral agreement may also be a contract for a longer period of time, e.g., the Merck-InBio agreement on the collection, screening, and utilization of genetic resources from the Costa Rican tropical forest. The third potential category of a bilateral exchange system for PGRFA is the exchange of germplasm for financial resources. Hence, in addition to the time horizon, the exchange system may also differ with respect to the means of exchange: wild material for improved germplasm as well as wild material for technology or financial transfer.

A market system for the exchange of PGRFA will be a highly developed organization. This system must include the private interest in exchange of PGRFA and the social interest in the long-term conservation of PGRFA. There will not be only a need for an appropriate institutional framework, but the system will also require a practical system of enforcement and control.

The main institutional aspect for a private market system is the creation of a virtual market for genetically coded information on the Internet as a freely accessible database containing the world's entire available PGRFA (e.g., the World Information System and Early Warning System on PGRFA). Prospective users could call up the standardized genetically coded information they require and clarify the property rights of the resources. Prices for genetically coded information would develop stepwise depending on the technical advances made by users and the development of markets for end products, amongst other factors.

In addition to the information system a further system is needed to enable the transaction of genetically coded information from the supply to the demand side as well as to enforce any kind of compensation. This system could be a clearing house mechanism for the promotion of technical and scientific cooperation, serving the sustainable development of biological resources as mentioned in Article 18 of CBD or a "facilitator" to organize the transfer of genetically coded information, as was suggested by Lesser and Krattiger (1993).

The enforcement of any rights, as royalties or other internalization mechanisms is impossible without gathering all existing genetically coded information of an accession. At national level, the "Conservation and Service Center" could be responsible acting as a facilitator. It could claim any internalization of social benefits or any compensation by proving which genetically coded information was sent to which breeder. The center could act as the focal point and as a broker for all information on ex situ and in situ conservation activities in the country. In addition the center will have contact to the clearing house on an international level.

Such a system would help to reduce the search costs for the breeding industry to a minimum (Virchow 1999).

One successful example at international level is the "International Service for the Acquisition of Agri-Biotech Applications" (ISAAA), which as an institution is playing the role of "an honest broker" between the different interest groups in technology transfers (van Zanten 1996).

Assessment of the Different Exchange Mechanisms

An imperfect market, causing some specific transaction costs characterizes the present situation. So far, the whole PGRFA conservation system is based on non-market, i.e., public interactions. The demand side for PGRFA, especially the breeders, the biotechnology industry, and the farmers, has been benefiting from the present system, participating only partially in the costs of conservation and exchange, and above all sharing only a minor part of the existing transaction costs of the conservation and exchange system. Asymmetric and rudimental information as well as an institutional framework lacking a legal system which defines the individual property rights for PGRFA as well as their transfer, are the specific problems hindering the development of a market-system with minimal transaction costs for PGRFA conservation and exchange.

With an understanding of why transaction costs play a vital part in the conservation and exchange system of PGRFA, institutional arrangements must be found, which present the second best solution. This solution should meet the Kaldor/Hicks criterion, e.g., the over-all PGRFA conservation and exchange system is only then efficient when the additional costs (including the benefit losses) of the establishment and enforcement of the system are less than the additional benefits resulting from the new system.

An efficient system of conservation and exchange of PGRFA has to meet three criteria:

- to provide sufficient incentives at the local, national and international level for the safe conservation of PGRFA,
- to enable a sustainable utilization of PGRFA, mainly in agricultural breeding, and
- to guarantee a "fair and equitable sharing of the benefits" according to CBD and a similar sharing of the burdens of conservation and utilization.

When creating a new conservation and exchange system for PGRFA or improving the existing informal system, one must keep in mind, that a system will only be enforced, if the resulting benefits exceed the transaction costs of enforcement.

The main advantage of a <u>multilateral system of PGRFA exchange</u>, in which all countries participate, is that it can only produce winners because each single participant gains access to more genetic material than the country itself can contribute. Furthermore, a formal multilateral system of exchange may have an advantage over the present informal system, in that more transparency and certainty may exist with respect to the rights and obligations of the members on ownership, access and benefit-sharing (IPGRI 1996). The present informal multilateral system is based on free access on the one hand and some – still not defined – compensation in the form of financial or a technology transfer or some kind of internalization on the other hand. The multilateral system is conceptualized as a *"... framework for a system guided by a set of mutually agreed rules ..."* including bilateral and multilateral agreements (IPGRI 1996: 61).

Not all participants, however, will profit equally from such a system. To base compensation merely on the number of species or varieties contributed to the multilateral system's common, internationally accessible pool would be too simple a solution. It would bear the threat of an adverse selection. Not all varieties will have the same valuable level of genetically coded information. Some varieties will have more unique information than others will. Hence, varieties with important, i.e., higher valued genetically coded information will be underpriced and will subsidize the less valued varieties, if all traditional varieties are treated as having the same value in a multilateral exchange system. If the countries or other suppliers of PGRFA are able to obtain the differences, they will try to take the more valuable varieties out of the multilateral exchange market and try to sell them independently on the basis of bilateral agreements. Consequently, the average quality of the regular PGRFA market will be reduced, which would lead to a reduction in the price. This tendency is increased if the exchange system presents a framework in which different kinds of agreements can be signed, including bilateral contracts. Hence, the incentive will cause the countries to negotiate the most valuable germplasm in bilateral agreements because of the high demand, and the less demanded germplasm in the multilateral compensation pool.

According to IPGRI (1996) the main advantages of the bilateral exchange system are its flexibility in terms of negotiations, adoption and fulfillment of the contract, the good exploitation of respective comparative advantages, and low overhead costs because of missing permanent institutional structures.

The main structural disadvantage of bilateral agreements is related to the issue of benefit sharing. In contrast to pharmaceuticals, modern varieties are derived from other very different varieties, lines and germplasm. If benefit sharing must be realized by crediting the cascade effect involved in breeding, the benefit distribution through specific agreements seems to be operational, only if countries are involved as recipients from the benefits. But even then, there needs to be some intelligent infrastructural solution. Taking the Veery wheat released by CIMMYT in 1977 as an example, the complexity of a benefit sharing system may be visualized. The Veery wheat lines were developed from approximately 3170 crosses, made between 51 individual parents originating in 26 countries around the world. 62 varieties were released from the Veery lines and cultivated on approximately 3 million hectares around the world. (Skovmand, quoted in IPGRI 1996: 26). Another question is whether every genetically coded information, integrated in the new variety at one time or the other, is equally credited or whether there should be any gradation depending on the novelty or the specific impact of the genetically coded information. In other words, will there be a possibility to assign a marginal value to each genetically coded information's contribution to a newly bred variety?

One of the most important arguments given by IPGRI (1996) and COOPER et al. (1994) for a multilateral exchange system is the problem of benefit agreements between a breeding company or a country and all the countries from which the incorporated individual parents originate. This problem is determined by the high grade of interdependence of the countries in regard to the origin of the utilized PGRFA in a country. According to their arguments, the transaction costs would be too high for such an agreement. As mentioned above, through an intelligent agreement system the transaction costs may be reduced to a reasonable level. Furthermore, by adjusting the benefit agreements of PGRFA utilization to the breeders' protection rights, a practical solution may be feasible: if the Breeder's Privilege is kept in place, the benefits of utilizing germplasm of traditional varieties should be restricted to new incorporated germplasm solely. Only the gene-owners who supplied new PGRFA to the breeding success should be credited for their PGRFA and not those who have supplied PGRFA in the former breeding process while already incorporating their PGRFA before the release of an older variety. If the Breeder's Privilege is abolished and patents are introduced for all varieties the benefit system for genetically coded information derived from traditional varieties has to be adjusted. If breeders cannot utilize an older variety for further research and development without crediting the owner of the incorporated old variety, all gene-owners of germplasm derived from traditional varieties through the whole breeding process have to be credited as well.

Additionally, an institutional framework is needed for a pure bilateral exchange system as well. The relevant information could not be distributed evenly without a clearing-house mechanism or some other system of information distribution. Hence, the transaction costs of the system would increase because of disproportionate search costs.

The main advantage of a market system of PGRFA exchange is the high flexibility concerning the incentive for conservation and the system for benefit sharing. Due to technological development the value of genetic resources will not stay constant over time. Consequently, all exchange mechanisms without a free price regulating institution will end up with political defined values of genetic resources. If the information of the genetic resources and their value can be openly accessed and the property rights for genetic resources are clarified, the market solution may reflect the best present value estimation of genetic resources.

The main disadvantage of the system is similar to that of the bilateral exchange system. As long as the benefits have to be shared with the owners of all ancestors of the variety, the transaction costs of benefit sharing as well as the control systems are too high. By reducing the benefit sharing to the source of genetically coded information the transaction costs will be reduced as well. Furthermore, the development of new technologies may reduce the costs of control measures. Basically, the techniques are now available to utilize molecular markers in the context of variety protection (van Laecke et al. 1995). Further development of molecular techniques will theoretically improve the level of distinction and allow researchers to distinguish even between closely related cultivars. This may allow the identification of essentially derived varieties (Semon 1995). Hence, modern techniques may prove to be useful in determining the probable identity and origin of landraces, genotypes and genes. However, it is unlikely that these techniques can be utilized in the context of agreements for access to PGRFA due to the inherent great variability in most landraces and populations (FAO 1995b).

This will be the crucial point for the establishment of any market exchange system. It will be successful only if the additional costs of the establishment and management of the market system will be less than the additional benefit. Additional costs will emerge for the demand side through the new transaction of genetically coded information as well as through the control of the property rights. Additional benefit for the market system is the direct assignment of the value of PGRFA to specific genetically coded information. This increases the incentive for improved conservation activities.

Conclusions: The Way To Go

The pharmaceutical industry is heading to the negotiation of bilateral contracts between large corporations and national governments. The agricultural sector, however, appears to be moving towards a further consolidation of the existing multilateral system, because of its existing structure and the high transaction costs of other exchange systems (Cooper et al. 1994). Although the property rights are poorly defined for the moment, PGRFA's future conservation and exchange will depend on the sufficient incentives as a kind of compensation or internalization. The bilateral and the private exchange system of PGRFA may emerge from this system in the long run, after further development in the patent law and in property rights in general as well as in technology for the enforcement of any rights. Furthermore, it will be difficult eventually to establish an exchange system recognized over-all because of the heterogeneity of developing countries. The debate which exchange system to choose, and therefore which incentive system will be dominant, is the debate between agrobiodiversity rich and diversity poor countries as well as between technological rich and poor countries. The uneven distribution of agrobiodiversity among developing countries and the different grade of technology development discloses the fundamental controversy over the decision between a multi-lateral system (compensation of social costs) and a market solution (internalization of social benefits) for the access to PGRFA.

Each country will favor an exchange system depending on its stock on PGRFA as well as on its ability to utilize their ex situ and in situ maintained plant genetic resources. The national capacity of genetic resources utilization depends on the country's technological state of crop improvement programs at present and in the future. Knowledge, infrastructure, and financial potential for meeting the requirements of further breeding activities, are the main determinants, which differ from country to country. Consequently, the prospects for the technological capacity for utilization of plant genetic resources in countries are diverse.

According to their breeding capacity and the availability of genetic resources the national utilization potential differs greatly from one country to another (see TABLE 1). Developing countries rich in PGRFA and with technological potential presently have comparative advantages for an internalization of the benefits resulting from PGRFA utilization and could win through a bilateral or private exchange system. Developing countries, rich in PGRFA but poor in technology potential, could win through the internalization of benefits (market solution), if adequate enforcement systems are implemented. On the other hand, because of high transaction costs for such an enforcement, these countries could also win through the compensation solution in a very broad multi-lateral system. PGRFA poor developing countries, however, will push a compensation solution, based on a multi-lateral system in which compensation is allocated by unspecified criteria. This would be the only means in which those countries could benefit from the international exchange of PGRFA, besides benefiting in the supply of modern varieties through international public and private channels.

TABLE 1 Country Specific Preferences for an Exchange System

	Country's supply of PGRFA:	
Degree of technological potential:	**High supply**	**Low supply**
high potential	Market for GCI	Market for GCI (multi-lateral system)
low potential	multi-lateral system (Market for GCI)	multi-lateral system

Nevertheless, regardless of which exchange system will dominate, key requirement for any system is an adequate incentive system, which:

(1) ensures the crediting of the supplied PGRFA,
(2) secures the conservation of PGRFA (in situ as well as ex situ) on a national and an international level, and foremost
(3) enables the reduction of transaction costs for PGRFA exchange through a comprehensive information system.

The system of internalization would tend to a bilateral exchange system or imply a market approach, where either the countries or the farmers, individually or as community, will profit directly from any exchange of genetic resources. Meanwhile the system of compensation would suggest a more general, non-targeted approach for a multilateral exchange system. One key role for the compensation system is the establishment and utilization of an international fund as the nodal point for financial transfer from PGRFA users (countries or private companies) to PGRFA suppliers. The basic framework for the "International Fund for Plant Genetic Resources" was adopted by FAO Resolution 3/91, which agreed *"... that Farmers' Rights will be implemented through an international fund of plant genetic resources, which will support plant genetic conservation and utilization ..."* (FAO 1996b, paragraph 16). Matters related to the legal status, policies, priorities, and parties as well as to the financing are, however, still under discussion.

Regardless of how the international exchange system and financing mechanisms for the management and utilization of agrobiodiversity are ultimately framed, the value of genetically coded information can never be determined a priori but rather only from an a posteriori observation. The value of genetically coded information will be determined by their success in breeding and biotechnology. In order to remain viable any system must therefore sooner or later provide mechanisms of profit sharing. The benefits will be not only shared between those, who maintain genetic resources and those who utilize these resources, but there will be also a competition among those maintaining genetic resources for the best quality of genetic resources and the most efficient ways of distributing the genetically coded information. Without such a mechanism there is a high risk that eventually the conservation of genetic resources will be suboptimal, the financial resources spent inefficiently or consumed by high transaction costs and the demand side will not be supplied with the best quality of genetically coded information in the optimal amount.

The debate which exchange system to choose seems to be the first step towards a market or bilateral exchange system. It will only succeed the multi-lateral exchange system, however, if the transaction costs of search and monitoring can be reduced by the development of the relevant monitoring technology.

Endnote

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References

Artuso, Anthony. 1994. Economic Analysis of Biodiversity as a Source of Pharmaceuticals. Paper presented at the Symposium on Biodiversity, Biotechnology and Sustainable Development at IICA Headquarters, San Jose, Costa Rica, April 12-14, 1994.

Cooper, H. David, Elizabeth Cromwell. 1994. In Situ Conservation of Crop Genetic Resources in Developing Countries: The Influence of Economic, Policy and Institutional Factors. Draft Discussion Paper 1. Rural Resources Management Group, Rural Poverty and Resources Research Programme. Funded by Natural Resources and Environment Department, ODA.

de Kathen, André. 1996. Gentechnik in Entwicklungsländern: Ein Überblick: *Landwirtschaft*. Umweltbundesamt, Berlin.

FAO. 1993a. Harvesting Nature's Diversity. FAO, Rome.

FAO. 1993b. International Undertaking on Plant Genetic Resources. Commission on Plant Genetic Resources. Fifth Session, Rome, 19–23 April, 1993. CPGR/93/Inf.2. FAO, Rome.

FAO. 1995a. Report of the Sixth Session of the Commission on Plant Genetic Resources, 19-30 June 1995, *Document CPGR*-6/95 REP. FAO, Rome.

FAO. 1995b. Revision of the International Undertaking. Stage Three: Legal and Institutional Options. Commission on Plant Genetic Resources, Sixth Session, 19-30 June. FAO, Rome.

FAO. 1996a. Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. FAO, Rome.

FAO. 1996b. The Fourth International Technical Conference in the Context of the FAO Global System for the Conservation and Utilization of Plant Genetic Resources for Food and Agriculture. International Technical Conference on Plant Genetic Resources. *ITCPGR/96/INF/2*. FAO, Rome.

FAO. 1997. Progress Report on the Global System for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. Commission on Genetic Resources for Food and Agriculture. Seventh Session, 15-23 May. FAO, Rome.

FAO. 1998 The State of the World's Plant Genetic Resources for Food and Agriculture. FAO, Rome.

Gass, Thomas. 1996. Access to Plant Genetic Resources, Farmers' Rights and Equitable Sharing. Presentation at the Industry workshop: *The Conservation and Utilisation of Plant Genetic Resources for Food and Agriculture*. February 15-16. Basel.

Hammer, Karl. 1995. Personal Communication. *Institute of Crop Science and Plant Breeding*, Gatersleben. Head of Genebank.

IPGRI. 1996. Access to Plant Genetic Resources and the Equitable Sharing of Benefits: A Contribution to the Debate on Systems for the Exchange of Germplasm. *Issues in Genetic Resources No. 4.* IPGRI, Rome.

Kloppenburg, Jack R., Daniel Lee Kleinman. 1988. Seeds of Controversy: National Property versus Common Heritage. In: Jack R. Kloppenburg (ed.): Seeds and Sovereignty. The Use and Control of Plant Genetic Resources. *Duke University Press*, London. 173-203.

Lesser, W., A. F. Krattiger. 1993. Negotiating Terms for Germplasm Collection. Working Paper No. R8W. *International Academy of the Environment*, Geneva.

OECD 1992. Biotechnology, Agriculture and Food. Paris.

Plucknett, D. L., J. I. Cohen, and M. E. Horne. 1990. Role of the International Agricultural Research Centres. In: Persley, Gabrielle J. (Ed.): Agricultural Biotechnology. Opportunities for International Development. *University Press, Cambridge*. 400-414.

Semon S, 1995 The Impact of the UPOV 1991 Act upon Seed Production and Research. Ms.C. Thesis, *University of Edinburgh, Scotland.*

Svarstad, Hanne. 1994. National Sovereignty and Genetic Resources. In: Vincente Sanchez, Calestous Juma (eds.): Biodiplomacy – Genetic Resources and International Relations. *ACTS Press, Nairobi*. 46-65.

UNEP (United Nations Environment Programme). 1994. Convention on Biological Diversity. Text and Annexes. *Interim Secretariat for the Convention on Biological Diversity, Geneva Executive Center*. Switzerland.

Van Laecke, K., E. Van Bockstaele, M. De Loose. 1995. Evaluation of RAPD-Markers for the Identification of Ryegrass Varieties. UPOV Working Group on Biochemical and Molecular Techniques and DNA Profiling in Particular, *UPOV Paper BMT/3/3*.

van Zanten, Jasper. 1996. Technology Transfer including Biosafety. Presentation at the Industry workshop: *The Conservation and Utilisation of Plant Genetic Resources for Food and Agriculture*. February 15-16. Basel.

Virchow, Detlef. 1999. *Conservation of Genetic Resources: Costs and Implications for a Sustainable Utilization of Plant Genetic Resources for Food and Agriculture*. Springer. Heidelberg.

Virchow, Detlef, Murthi Anishetty. 1999. Regional Funding: Costs of Conservation and National and International Roles. *ACIAR Workshop*, Lea, PNG. March 1999.

Vogel, Joseph Henry. 1994. Genes for Sale. Privatization as a Conservation Policy. *Oxford University Press*. Oxford.

von Braun, Joachim, Detlef Virchow. 1997. Conflict-Prone Formation of Markets for Genetic Resources: Institutional and Economic Implications for Developing Countries. *Quarterly Journal for International Agriculture* 1/1997: 6-38.

WIEWS 1996. Datainformation from the World Information and Early Warning System, *FAO.*

Wright, B. D. 1998. Intellectual Property and Farmers' Rights. In: Evenson, R. E., Gollin, D., Santaniello, V. (eds.) *Agricultural Values of Plant Genetic Resources*. CAB International: Wallingford, UK, 1998.