GFAR

GLOBAL FORUM ON AGRICULTURAL RESEARCH
FORUM MONDIAL DE LA RECHERCHE AGRICOLE
FORO GLOBAL DE INVESTIGACION AGROPECUARIA

Document No: GFAR/00/17-04-04
Distribution: SUB-PLENARY 1
Date: July 15, 2000

GFAR - 2000
May 21 - 23
Dresden, Germany

Strengthening Partnership in Agricultural Research for Development in the Context of Globalization

TRANSACTION COSTS OF GERMPLASM EXCHANGE UNDER BILATERAL AGREEMENTS*

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* This paper is part of the background papers that have been prepared at the request of the GFAR Secretariat, in order to provide a technical background to GFAR stakeholders in their deliberations on the policy issues that are being analyzed in the "Initiative on Genetic Resources for Food and Agriculture". The paper is solely the responsibility of the authors, and does not necessarily represent the views of GFAR, nor of any of its stakeholders.

Transaction costs of germplasm exchange under bilateral agreements[1]

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April 2000

Executive summary

This paper considers the likely transaction costs that would be entailed in exchanging plant genetic resources for food and agriculture under bilateral agreements. Such transaction costs are hard to estimate, and our estimations could only be based on experiences in related fields and merely form a best possible educated guess. However, the actual monetary figures produced in this study are probably not as valuable as the discussion on how they were generated and, more importantly, what they imply for a complete comparison of costs and benefits.

International germplasm flow over the past decades for specific crop groups, and the number of source countries and destination countries involved, were estimated. Four different scenarios with a varying degree of germplasm exchange under bilateral agreements were assumed and likely transaction costs under these four scenarios were estimated. These scenarios range from an approach by which all exchange takes place under bilateral arrangements to an approach by which all germplasm for food, but not for industrial crops, falls under the Multilateral System of Facilitated Exchange and Benefit Sharing. Only additional costs, not incurred under the MLS, were taken into account, i.e. costs for negotiating bilateral agreements, and tracking and monitoring the use of germplasm under bilateral agreements.

Total annual costs were estimated from $1.2 – 1.9 million for a MLS including bilateral arrangements covering industrial crops to $ 32 - 128 million for bilateral arrangements covering all crops. These costs were compared with current annual investments in the maintenance of Plant Genetic Resources for Food and Agriculture (PGRFA) by the private and public sectors and with the estimate of funds at an annual basis allowing implementation of the Global Plan of Action. Estimated transaction costs appear quite significant and of the same order of magnitude as current investments for the scenario with only bilateral agreements.

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1. Background

Until recently farmers and the professional breeding sector have relied on genetic materials, in the public domain or in the market, being freely available for use in research and breeding. This is reflected in the current FAO International Undertaking on Plant Genetic Resources for Food and Agriculture, and the UPOV Convention. UPOV for example, allows the genetic resources in any protected variety to be exploited for further use, under the “breeders’ exemption”.

As a consequence of the adoption of the CBD, which reaffirmed the sovereign rights of States over their biological resources, governments are currently negotiating the revision of the International Undertaking, in harmony with the CBD, in the FAO Commission on Genetic Resources for Food and Agriculture. The Conference of the Parties to the CBD has recognized (by Decision II/15, in 1995) the special nature of agricultural biodiversity, its distinctive features and problems needing distinctive solutions, and in this context has supported these negotiations for the revision of the International Undertaking.

In the framework of the revised International Undertaking, countries are developing a Multilateral System of Facilitated Access and Benefit-Sharing (MLS) for Plant Genetic Resources for Food and Agriculture (PGRFA), on the basis of countries’ interdependence in regard of such resources, and their importance for food security. Exchange of crops which are brought into the MLS will not be dependent on (bilateral) agreements whereas all the other crop germplasm will probably be exchanged through bilateral agreements. In the framework of the negotiations on the revision of the International Undertaking governments are currently discussing a list of crop genepools to which the MLS will apply.

At the same time, many governments are currently considering legislation on access to biological diversity in general, by way of implementation of the CBD. The objective of such legislation is to regulate “bioprospecting”, that is foremost the identification amongst wild resources of bio-active compounds and their exploitation through the development of pharmaceuticals. This legislation will most often be of a “bilateralist” nature. Indications are that such legislation may not take into account the special nature of agricultural biodiversity and the needs of agriculture, nor may it recognize that most countries are net importers of PGRFA.

In this context, a high level international Panel of Experts on Access and Benefit-sharing, which convened in Costa Rica, 4-8 October 1999 within the framework of the CBD, recognized that “there is a risk that access legislation under consideration in a number of countries might foreclose or restrict the option of multilateral approaches that those same countries may be pursuing in international forums”. Furthermore, the Panel of Experts concluded that “in developing national legislation on access, Parties [to the CBD] should take into account and allow for the development of the multilateral system to facilitate access and benefit-sharing for plant genetic resources for food and agriculture”, as discussed in the negotiations for the revision of the Undertaking.

The 1999 FAO Conference also stressed the importance for countries that are developing relevant legislation “to do so in such a way that would enable them to take into account and allow for the elements of this (IU; note authors) new international agreement”.

2. The Likely Effects of Bilateral Arrangements for Access to Plant Genetic Resources for Food and Agriculture

This paper considers the likely transaction costs that would be entailed in exchanging plant genetic resources for food and agriculture under bilateral agreements. To protect the interests of the parties in bilateral agreements specific regulatory and other conditions have to be fulfilled. Such arrangements may vary substantially in size, coverage and complexity.

The objective of this study is to enlarge our understanding of transaction costs involved in the effective functioning of bilateral agreements, including effects on the access and utilization of PGRFA by various stakeholder groups. To achieve this objective the following approach has been adopted.

1. First, we estimated **germplasm flow** over the past decades, in order to obtain an overview of the size of germplasm exchange for specific crop groups, as illustrated for specific crops. The databases of SINGER, the Centre for Genetic Resources the Netherlands (CGN), the Nordic Gene Bank and the National Institute of Agrobiological Reources (NIAR) of Japan served as data sources, and limited data of USDA/ARS were added. Taken together, these data obtained from international and national germplasm holdings probably give a reasonable impression of germplasm flows between countries for various crop groups. For the purpose of this study we distinguished cereals, grain legumes, root and tuber crops, forages, vegetable crops, and industrial crops. In addition to the extent of germplasm exchange, we investigated the numbers of source countries and destination countries involved.

2. We then assumed **four different scenarios** with a varying degree of germplasm exchange under bilateral agreements according to crop group. With these scenarios we attempt to envisage the consequences of alternative, yet fictive outcomes of the debate on the renegotiation of the International Undertaking. To this end, we have selected discrete options from the theoretically unlimited continuity of possible outcomes of the debate. These scenarios were chosen because they surface in these or similar forms in current discussions in several platforms and because we regarded them as representative in their conseqences for many more potential variant options.

3. Furthermore, we reasoned that the major elements contributing to **additional transaction costs** stemming from the bilateral nature of agreements would be the following:
   - **Negotiating** agreements;
   - **Tracking and monitoring** the use of germplasm, consisting primarily of pre-distribution fingerprinting of accessions and post-distribution monitoring of use by several means.

These elements would be new elements, and consequently the costs arising from the introduction of these elements are additional and not just a redistribution of existing costs.

4. We then combined the conclusions of the third step with the data of the first two steps, and estimated the **total number of agreements** for each of the four scenarios which would be needed to cover the current level of exchange.

5. Subsequently, we estimated a range of **values for the transaction costs** identified in step 3 above. In the first place we attempted to approximate the negotiating costs to come to an agreement. Although costs of arriving at agreements are known for other issues, it is hard to know how trust or lack of trust between potential parties in an agreement will influence the costs to arrive at germplasm exchange agreements. In the second place we calculated the costs involved in tracking and monitoring the use of germplasm, including costs incurred at the pre-distribution and post-distribution stages. As negotiating costs, monitoring costs are hard to estimate. Our estimations could only be based on experiences in related fields (IPR) and form a best possible educated guess in translating these experiences to the issue of bilateral germplasm exchange at hand.

6. In the final step, we **added up** the three major costs items (negotiating, fingerprinting and tracking). We then related the costs stemming from bilateral agreements under each of these four scenarios with figures on public and private sector investments in agricultural research and development available to us, including germplasm conservation and improvement. On this basis, we tried to arrive at a preliminary assessment regarding the extent to which such costs might be acceptable or feasible for those parties which will have to bear these additional costs.

Before proceeding with our first step, it is worthwhile stressing a particular notion that is relevant to this study. The acceptability of transaction costs should not only be judged by comparison with total costs incurred in maintaining PGRFA. From an economic perspective, a common approach is to compare costs with benefits. A cost-benefit analysis can be undertaken at various levels including, among others:

- **Individual actor** perspectives, such as genebanks, breeding companies, research organisations, etc., that look at direct consequences for the actor involved only;
- **National level** perspectives, that add up the costs and benefits for all actors within a country and where one would expect a difference between net provider and net user countries;
- **Regional or global** perspectives, that add up the costs and benefits for a number of, or all countries.

Costs and benefits thus vary according to perspective. A benefit from one perspective might be a cost from another (e.g. benefit-sharing in the form of financial compensation)[6]. Whether total expected benefits outweigh costs, or

[6] Note also that an analysis of costs and benefits of a scenario or situation is always undertaken with reference to the costs and benefits in an existing or baseline situation.

vice-versa, can be expected to vary according to the perspective being taken, and thus to provide the basis for different negotiating positions.

A complete cost-benefit analysis of bilateral arrangements would examine this balance at the various levels but is outside the scope of this paper. This study may only provide elements that could fit into such a comparison. The approach being taken is to study additional costs which are encountered under bilateral exchange arrangements but not under the MLS.

Figure 1 illustrates how transactions costs from bilateral arrangements would be incurred by both providers and users of germplasm (distinguished as either individual actors or at a national level). Any benefits captured by providers would be essentially a shift from the users' account to that of the providers: any benefit to the provider will form a cost to the user. On a global level, there are no additional benefits, simply increased costs. This figure does not even mention the "indirect" costs arising from a world of bilateral arrangements in which it can be expected that far less germplasm exchange will take place. These indirect costs, in the form of foregone research benefits, are extremely difficult to quantify, but potentially the most important consequence of a trend towards bilateralization. In particular, a decrease in information sharing through public databases on the performance of exchanged germplasm might form the biggest impediment to future germplasm use.

We do not attempt to weigh up the benefits and costs for even one actor. But we do, in our discussion of the acceptability of estimated transaction costs below, begin to relate them to other elements that would enter the "balance sheet". In Figure 1 we explain which transaction benefits and costs will be encountered by providers and users, and how at the global level costs by definition will increase upon introduction of bilateral agreements. Providers will encounter both benefits and costs, whereas users will merely encounter costs under effective bilateral agreements.

Figure 1: Additional Costs and Benefits of Bilateral Arrangements

	Providers	**Users**	**Global (sum of providers & users)**
Benefits	+ captured benefits (=CB)	– CB	0
Costs	+ transaction costs providers (TC1)	+ transaction costs users (TC2)	TC1 + TC2
Net benefits (benefits – costs)	CB – TC1	– CB – TC2	– TC1 – TC2

3. Germplasm Flow

The first step is an approximate estimation of the current extent of germplasm exchange. This was undertaken for a number of specific crops that were regarded as approximate indicators for broader crop groups: cereals, grain legumes, root and tuber crops, forages, vegetable crops, and industrial crops. The actual dimension (or size) of germplasm exchange can be partly construed from figures on flows of germplasm available from genebanks. For this study we have collected a (limited) set of data on germplasm exchange quantities for some selected representative crops and by some representative collection holders, with the purpose to formulate some reasonable estimates of the number of transactions on an annual basis. Figures (see Table 1, end of document) were calculated from the SINGER database covering the germplasm of selected IARCs of the CGIAR, as well as from databases from two active European genebanks, that of the Netherlands (CGN) and the regional Nordic Gene Bank (NGB), as well as the Japanese genebank NIAR. Some additional data were obtained from USDA. Separate studies, [one of which is featured as another micro-paper in this GFAR initiative (Fowler and Smale, 2000)], are examining these flows in more detail. The figures in Table 1 support estimates of the number of germplasm accessions distributed by genebanks at approximately 100,000 per year.[7]

An analysis of user types of germplasm in destination countries shows that for most crops studied the public domain, consisting of NARS, public genebanks, and universities, is the largest user category. The share of private sector users of exchanged germplasm varies by crop, being less than 10% for rice, sorghum, pearl millet, chick pea, cowpea, groundnut, pigeon pea, and sweet potato, up to 50% and more for vegetables and other germplasm from the European genebanks. An overview of national genebanks from India, Japan and the USA (Box 5.4, Ten Kate and Laird) mentions averages of 33%, 4% and 11% respectively as figures for use by the commercial sector. Table 7.1 of the FAO State of the World (1996) mentions commercial use figures for the CGIAR genebanks ranging from 0% for Phaseolus collections of CIAT and total collections of ICARDA and IITA, to 6% for CIAT forage legumes collections, 7% for ICRISAT collections and 8% for the CIMMYT maize collection.

As can be seen in Table 1, OECD countries received less than 15% of the total samples of IARC-distributed accessions, for crops such as rice, sorghum, pearl millet, chickpea, groundnut, pigeon pea and sweet potato, whereas these countries received more than 50% of the samples distributed for vegetables and the other crops of CGN.[8]

In general, the public sector and non-OECD countries are the largest beneficiaries of the samples originating from the CGIAR genebanks, whereas the regional role and the larger share of the private sector in total breeding efforts is exemplified in the case of the European genebank collections by the higher share of private sector and OECD destination countries. Even for these European

[7] The difference between this estimate and those used elsewhere (IPGRI, Issues in Genetic Resources No. 5) are largely due to the focus here on exchange of genebank germplasm and the omission of the distribution of improved breeding materials in Table 1. As we proceed with an analysis based on the number of sources and destinations, and thus the number of agreements necessary, the number of accessions exchanged becomes less important than the number of actors involved. In our view, it is likely that the number of actors involved in exchange of genebank accessions will be a reasonable approximation of the number of actors involved in total global exchange of plant germplasm.

[8] Figures were not characterized for user geography for accessions distributed by NIAR, Japan.

genebanks, a considerable portion of total exchange is towards non-OECD countries.

Although breeding products in the North continue to be developed from genetic resources obtained from the South, South-South transfers remain significant among developing countries as do exchanges between industrialised countries.[9] Over the years, many countries in the South have built extensive capacity to innovate and add value to some of their genetic resources. More and more, the "grand bargain" is between different actors in civil society, rather than between states (Ten Kate and Laird, 1999).

The analysis above is used in estimating the number of agreements and the various actors involved, but we turn first to formulating a number of likely scenarios concerning the extent to which exchanges could take place under a set of bilateral agreements on exchange.

4. Scenarios involving Bilateral Approaches towards Exchange

Recent negotiations on the revision of the International Undertaking have concentrated to a certain extent on the possible list of crop genepools that could fall under the Multilateral System of Facilitated Access and Benefit-Sharing (MLS). The two "extreme" options are that, in one case, all germplasm for food and agriculture falls under the MLS and, in the other, that all exchange takes place under bilateral arrangements. In between these two extremes there is a range of options. For our study, we formulated four scenarios as detailed in Table 2. These scenarios were chosen because they surface in current discussions in several fora and because they examplify the consequences of choices for a larger or more limited list of crop genepools.

Table 2: Scenarios of crop coverage for the multilateral system (MLS)

	A	B	C	D
Crops covered	None (all exchanges under bilateral agreements)	Included* CGIAR collections & national cereals collections	Included CGIAR collections & national cereal and grain legume collections	All included food crop collections (only non-food crops under bilateral agreements)

*By included is indicated that not all germplasm under given jurisdiction will automatically qualify for coverage under the MLS, depending on legal status (public or private) and utility (conservation collections vs. breeding or research collections)

5. Additional Transaction Costs under Bilateral Exchanges

Our third step was to examine the transaction points that are specific for bilateral exchange agreements. A number of costs are incurred in the exchange of PGRFA. Costs incurred by suppliers of PGRFA for collecting, characterising,

9 See Fowler and Smale (2000) on South-South transfers.

evaluating and distributing genetic resources are quite considerable. However, such costs are part of what might be termed the “production process” of exploiting genetic resources, and - although considerable and a heavy burden for collection managers - they are costs that have to be covered under either multilateral or bilateral agreements of exchange. Thus they are not included in this study.

Transaction costs involved in bilateral exchange are likely to begin when those seeking genetic resources engage in acquiring information about possible sources of desirable germplasm accessions.

The most significant transaction costs begin when suppliers and demanders come together to negotiate an exchange of germplasm. Both actors incur costs in the process of arriving at an agreement on a range of aspects, including the scope of use, financial compensation, and obligations of the parties to the agreement. These are direct and very tangible, financial costs (e.g. time of staff involved, legal fees, etc.) borne by the demanders and suppliers, and recurring for each agreement.

Further transaction costs are associated with monitoring the agreed use of the material under contractual arrangements. Some of these transaction costs may be borne by the demander in the form of reporting requirements. But based on current experience, the more significant transaction costs are likely to be incurred by the supplier in the form of monitoring the use and ensuring that the exchange agreement has not been transgressed. Additional transaction costs would be incurred when enforcement actions are undertaken in the case of a suspected failure to abide by the terms of a contract, culminating possibly in private legal action.

For our analysis, we have distinguished three different types of transaction costs:

- Negotiation costs of agreements
- Pre-distribution tracking costs (fingerprinting of accessions)
- Post-distribution tracking costs (monitoring of use, molecular analysis)

If bilateral exchange of germplasm would become the predominant mechanism, it is unlikely that bilateral agreements would be concluded per exchange transaction. We have assumed that the transaction costs implicated by agreements concluded on a per-exchange basis would be too high to be worthwhile, providing a rationale for exchangers to conclude broader agreements on a per crop basis, or even more broadly.

Our next step focuses on estimating the number of agreements that are needed. Admittedly, the assumption that broader agreements would prevail has resulted in rather conservative estimates of the transaction costs involved in bilateral arrangements.

6. Number of bilateral agreements

The number of agreements needed rather than the number of exchanged samples seemed to us the more realistic parameter to estimate negotiating costs.

In the fourth step we have therefore estimated the total number of agreements for each of the four scenarios which would be needed to cover the current level of exchange under bilateral arrangements.[10] It has been assumed that such agreements would, on average, last five years. The results of this step have to be interpreted with great care, since assumptions on the investments in negotiating could not be underpinned with hard data.

The total number of agreements estimated to be necessary under each of the four scenarios identified above is presented in Table 3 and explained below.

Our estimates of the number of agreements are based on the following figures regarding annual exchange of germplasm. Total transfer may amount up to 800,000. International transfer through the CG system has been estimated at 650,000 for food crops, consisting of 500,000 samples of improved germplasm and 150,000 from the in-trust collections (IPGRI, 1996). We estimated non-CG transfer of food crops at 150,000, based on our own information and limited figures from Ten Kate (1999) and at 50,000 for non-food crops [Lesser, pers. comm.]). The estimate of 150,000 seems reasonable based on a comparison of the holdings of CGN, NGB and NIAR with their germplasm exchange levels; total holdings of these three genebanks of 260,000 accessions compare to an average yearly exchange of 8,000 accessions approximately, whereas total global holdings in national genebanks amount to 5,5 million, and would translate in 170,000 based on the exchange figures for the three genebanks mentioned. Figures of Ten Kate (box 5.4; 1999) show that only four large genebanks already distribute 60,000 accessions annually to foreign destinations.

Table 3: Agreements (per year) estimated to be involved under various scenarios of bilateral/multilateral exchange

Scenario	A Bilateral agreements only; no MLS	B Limited MLS including CGIAR collections and major cereal crops	C Larger MLS including CGIAR collections, major cereal and grain legume crops	D Bilateral agreements on non-food crops only
Agreements per year	400 – 2,000	200 – 500	80 – 200	20 – 40
Accessions exchanged under bilateral arrangements	800,000	150,000	100,000	50,000
Accessions to be fingerprinted per year[1]	48,000	9,000	6,000	3,000

1. See “Fingerprinting germplasm for exchange” further on in text for detailed description of calculation

Scenario A: It is expected that in the absence of the MLS, agreements would be of a multi-crop nature and cover a larger number of transactions between any two parties, in an effort to reduce transaction costs. Table 1 shows that the maximum number of source countries and of destination countries for the germplasm flows of crops included there is approximately 100. Although these numbers seem

[10] We have restricted ourselves to bilateral arrangements at this point and have not addressed the likely scenario that regional and sub-regional agreements would probably emerge if a multilateral system would not materialise.

quite high, one should take into account that, in addition to, or instead of states, private parties would become involved in bilateral exchange agreements. Therefore, 100 providers and 100 demanders seem to be reasonable, upper limit figures.[11] This would result in a maximum of 100 times 100, or 10,000 agreements in total.

However, the available figures on current exchange patterns may not form a precise reflection of the numbers of actors actually involved. For example, the number of source countries in Table 1 corresponds to sources of all accessions in collections. Not all of those have been distributed to destination countries. Furthermore, the number of destination countries over the last two decades may not correctly indicate which users are still current demanders.

The following assumptions were therefore made, to arrive at a lower estimate. Based on the figures in Table 1, we reasoned that per crop group (cereals, grain legumes, etc.) there would be at least 25 Northern countries or companies and 15 Southern countries that want to access germplasm, searching for specified valuable traits rather than for coverage of crop genetic diversity in general. This amounts to 40 demanders. Furthermore, by taking into account the limited number of countries that have been the source of most of the genebank accessions and the directed search expected under bilateral arrangements, we estimated that there would be at least 10 source countries or providers per crop group. This would add up to 400 agreements per crop group (40 times 10). However, given the fact that many different crops are involved, we assumed a five-fold more complex situation (agreements might be negotiated per crop group; different countries will be involved depending on the crop group), leading to approximately 2000 agreements as a lower estimate. Recalling that we have assumed that agreements will last, on average, five years, the lower and higher estimates would then correspond to a range of 400 – 2,000 agreements on a yearly basis.

Scenario B: If all included CGIAR collections and the included national collections in the major cereals rice, wheat, maize, sorghum and barley were included in the MLS, the germplasm exchange to be covered by bilateral agreements would reduce dramatically. However, on the basis of current exchange patterns, the number of source and destination countries for bilateral exchange would decrease much less, since many countries would still seek access for the crops not covered. Agreements might become less complex.

We assumed that half of all countries involved in scenario A lack sufficient breeding capacity and solely depend on the CGIAR institutes for advanced materials in the major staple crops. The number of destination countries would decrease to 50. Similarly, the number of source countries would reduce, since not all countries providing cereal germplasm would also act as a source for other crop groups. We also took into account that bilateral agreements would be needed for fewer crop groups. On this basis we estimated the total number of parties involved in bilateral transactions to be a maximum of 50^2 or 2500. The lower estimate (1,000) would assume that only half as many germplasm demanding parties might be involved as under scenario A, other assumptions

[11] Remember that we are trying to estimate, in the first instance, the transaction costs that would be entailed if bilateral arrangements were replicating the existing pattern and scale of transfers.

being unchanged including the number of source countries per crop group and the average five crop groups being distinguished in negotiations. On a yearly basis, these estimates would account for an average range of 200 – 500 bilateral agreements.

Scenario C: Under this scenario, even more countries would rely entirely on the MLS, covering all included cereal and grain legume collections. Our estimations assumed that any single agreement between two parties would cover all crops not under the MLS. We reasoned that 40 destination countries, harbouring substantial breeding capacities, as under scenario A, would now negotiate with 25 donor countries, representing the major centres of diversity for all remaining crops. This would result in a higher estimate of 1,000 agreements over a five-year period. A lower estimate of 400 agreements is based on the assumption that only 15 destination countries would negotiate with 25 donor countries. On a yearly basis, these estimates correspond to an average range of 80 – 200 agreements.

Scenario D: Under this scenario, all food crops would be covered by the MLS. To enable the exchange of industrial crop germplasm, 10 - 20 Northern countries or private parties and 10 Southern countries would each seek access to 5 source countries, mainly estate and fibre crops such as cacao, coffee, cotton, hemp, jute, oil palm, rubber, and tea. In many cases, agreements will now cover a single crop only. Thus the range of agreements is 100 – 200 which corresponds to 20 – 40 on a yearly basis.

It will be clear from the estimates above that not only the number of agreements but also the complexity of such agreements will decrease under increasing coverage of the MLS. Furthermore, our estimates of the number of agreements, a key parameter of our analysis, show a decreasing range with increasing coverage of the MLS. In other words, our level of uncertainty concerning the number of agreements is greater, the more crops fall under a bilateral approach.

Obviously, all of these estimates are speculative. We felt that they are a reasonably educated guess as to how many agreements would be necessary to cover the patterns of exchange that are currently taking place. Here we want to stress two major uncertainties. The first is that negotiating parties will be able to cover entire crop groups (scenarios A and B) or even all remaining crops (scenario C) under a single agreement. If this would be unrealistic, as many argue, the total number of agreements would increase substantially. The second essential assumption is that existing patterns of exchanges would not change substantially. However, presently we cannot predict that all these agreements would really come into being. In our concluding section, we briefly revisit the expected effects of estimated transaction costs on the number and pattern of agreements.

7. Costs of Negotiating Agreements

The costs of negotiating agreements consist essentially of personnel time on the part of both the provider and the recipient of PGRFA. Relatively senior, or qualified, personnel are required to negotiate and conclude exchange agreements. Whether internal or external expertise is used does not really affect the analysis undertaken.

Given the almost speculative nature of these calculations, we worked with a simple average cost per negotiated agreement. We assume that each side is required to invest, on average, 10 person-days into the negotiation and concluding of a single agreement costed at $500 per day. Thus the total, including both parties, is $10,000 per agreement. For anything more complicated than a standardized, “take-it-or-leave-it” agreement, this seems to us to be a minimum time necessary.

This is considerably more than the range of $100 (for a relatively simple material transfer agreement) to $1,000 (for complex agreements) used in IPGRI’s previous study (IPGRI 1996). But that study was based essentially on a *cost-per-exchanged-accession* basis.

In this study it is assumed that agreements between individual sources and users of PGRFA will cover a number of years (average of five years) and a number of accessions per crop or even crop groups. It is expected that this approach would offer efficiencies for the parties involved, in terms of transaction costs, by limiting the number of agreements, albeit more sophisticated and broader, that would be negotiated.

There are reasons for supposing that, in some cases, such agreements would be far simpler, such as those that might be concluded between two publicly managed genebanks. But in other cases, for example where the recipient is a breeding company, negotiations might become more complex. In these and other cases, for a number of providers of PGRFA such negotiations would serve to define the precise terms of benefit-sharing of genetic resources, and to extract terms that are as beneficial as possible. Furthermore, for a number of providers of PGRFA, a variety of public authorities may be involved, directly or indirectly, in such negotiations. These factors would all rapidly raise the amount of personnel time involved. Ten days per side might therefore be quite an underestimate.

There is good reason to suspect that these costs might decline after an initial period of five-to-ten years. An initial round of more intense negotiating and tracking of agreements would probably be necessary for the parties to develop a better sense of what the limits of negotiations are. A sense of trust would also develop among certain actors. In this sense, the estimate of $10,000 per agreement is seen as an underestimate for an initial period, but a possible overestimate in the longer term.

Table 4 presents the results when the estimate of $10,000 per agreement is multiplied with the estimated numbers of agreements from Table 3. Estimated negotiation costs range from $0.2-0.4 million under an MLS with bilateral arrangements limited to industrial crops to $4-20 million under a fully bilateral approach. This latter range is somewhat less than that first suggested by IPGRI (1996), reflecting the point above about the efficiencies of fewer but more encompassing agreements.

Table 4: Transaction costs under various scenarios of bilateral exchange agreements (costs in million US$ and on an annual basis)

Scenario	A	B	C	D
Negotiation costs	4 – 20	2 – 5	0.8 – 2	0.2 – 0.4
Pre-distribution tracking costs	7.7	1.4	1.0	0.5
Post-distribution tracking costs	10 - 50	5 – 12.5	2 - 5	0.5 – 1.0
Total Transaction Costs (TC)	22 - 78	8 – 19	3.8 – 8	1.2 – 1.9
Total TC as % of private breeders expenditures on maintaining genetic resources[1]	44 – 156	16 – 38	7.6 – 16	2.4 – 3.8
Total TC as % of public expenditures on PGRFA maintenance[2]	29 – 101	24 – 56	18 – 38	14 – 23
Total TC as % of estimated implementation costs of the GPA[3]	7 - 26	2.7 – 6.3	1.3 – 3.7	0.4 – 0.6

1. Source: ASSINSEL Web site, estimated at $50 million (see text)
2. Calculated using an average annual maintenance cost per accession (see text)
3. Estimate of $300 million

8. Pre-distribution Costs: Fingerprinting germplasm for exchange

It is assumed that suppliers of PGRFA will incur costs to be able to monitor the use of exchanged material to ensure, in particular, that any benefit-sharing provisions of contracts are not violated. In order to allow monitoring of use of exchanged germplasm, fingerprinting of accessions will be required. Current technology is able to identify original materials exchanged under an agreement. However, at this very moment, it is not yet possible to demonstrate the presence of small amounts of genetic information derived from germplasm exchanged under a bilateral arrangement with benefit-sharing provisions and representing valuable traits in a dissimilar genetic background. Options to follow the use of exchanged germplasm in breeding programmes and its representation in released varieties are still insufficient. However, appropriate technology which would allow to closely follow the use of germplasm is developing fast. In this regard, the increasing availability of microsatellite sequences for many crops, increasing knowledge of expressed genes and their alleles, and the development of high-throughput technology such as DNA micro-arrays are relevant.

Therefore, for this study we have assumed that technology will soon allow the provision of information necessary to verify, for example, whether released varieties contain in their parental lineage, materials covered under bilateral arrangements. To allow a financial estimation, it is also assumed that in the near future costs to cover such an analysis, would approximate costs currently incurred for fingerprinting exchanged germplasm.

The extent of fingerprinting taking place is assumed to vary according to how many crops, and thus accessions, fall under a MLS and how many are covered by bilateral agreements. The number of accessions estimated to be fingerprinted under the various scenarios is also presented in Table 3, calculated as follows.

We assume that the number of accessions under totally bilateral arrangements (scenario A) would be approximately 800,000. We have also assumed that total time needed to fingerprint all exchanged materials would be five years. In addition, identical materials might be handed out several times; redundancy in distribution is estimated at a factor of 3. This would mean that the number of accessions to fingerprint per year would be 48,000 accessions (= 800,000 accessions X 0.2 X 0.3).[12] In the case of scenario B, the total number of accessions under a bilateral approach would be approximately 150,000 (100,000 food crop and 50,000 industrial crop accessions) giving the number of accessions to fingerprint per year at 9,000. Under scenario C, the number of accessions would decline to 100,000 (50,000 food crop and 50,000 industrial crop accessions) leading to 6,000 accessions to fingerprint per year. Lastly, under scenario D only 50,000 industrial crop accessions would be covered under a bilateral approach, leading to 3,000 accession to fingerprint per year.

Fingerprinting can be regarded as an up-front cost and may be expected to decrease slowly over time as more and more accessions in collections are fingerprinted. On the other hand, as breeding materials constitute the majority of exchanged samples, this cost may decrease only slightly, and maybe more important, as technological options increase repeated investments to improve tracking of materials will be needed. We have assumed that the pre-distribution costs will continue to be necessary.

Table 3 presents the estimated number of accessions that would have to be fingerprinted under the various scenarios for bilateral exchange arrangements. Here, it is assumed that for self-pollinated species the number of plants to be fingerprinted would be approximately 5 per accession, and in the case of cross-pollinated species, approximately 20. We also assume that the proportion of cross-fertilising species of total exchanged germplasm would be approximately 20%. The average number of plants to be tested per accession would then be 8 [(80% x 5) + (20% x 20)]. The current costs of fingerprinting a single plant using existing technology is estimated at $20 based on CGN's experience. Thus, the average cost of fingerprinting an accession is $160 (= 8 x $20).

Table 4 presents, in the second row, the results of multiplying the $160 per accession costs by the estimated number of accessions to be fingerprinted per

[12] 0.2 represents the spreading of fingerprinting per accession over five years while 0.3 is the factor of 3 for redundancy.

year presented in Table 3 (e.g. under scenario A 48,000 accessions x $160 makes $7,68 million). Here we have included both genebank accessions as well as improved materials distributed by the CGIAR centers, since the technological limitations would not allow fingerprinting of the constituting genebank germplasm only. Thus the costs of fingerprinting are estimated as ranging from $0.5 million per year under a MLS with bilateral arrangements covering industrial crops (scenario D) to $7.7 million per year under a fully bilateral approach (scenario A). Since these figures represent costs for current technology, these figures should be regarded as an approximation.

9. Costs of Tracking Germplasm and Monitoring its Utilization

Tracking the use of germplasm by recipients and ensuring that agreements are not violated is an essential activity that would have to be undertaken under a bilateral approach, in order to monitor the compliance with the agreements. There is little sense in negotiating agreements with benefit-sharing provisions, in order to ensure that providers of PGRFA receive a “greater share” of the benefits, if these providers do not invest resources in ensuring that the recipients respect these agreements. This is particularly the case given the ease with which the lineage of newly registered varieties might be disguised, or not fully admitted.

The costs of tracking germplasm and monitoring its utilization consist essentially of monitoring and tracking the registration of plant varieties and of patents covering crop plant genes, including regulatory sequences, in attempting to verify varietal parentage. In exceptional cases, legal action may then be undertaken if misuse is suspected, even if financial costs are high and chances to deliver acceptable proof for misuse are limited. Alternatively, publicity might be sought to challenge suspected or identified misuse, or the FAO Commission might play a role here as a global governance body.

There are thus choices about whether and how to progress to the next stage. Furthermore, monitoring activities may only be undertaken on a regular, undisclosed basis (either by the provider or by third parties) that is meant to provide enough of a disincentive to any single recipient that their use of the germplasm might be subject to scrutiny. One can expect that there will be some economies of scale as the number of agreements increases. For example, if the same material is provided to a breeder in a country in which another breeder has also received the same material, then the additional costs of tracking this second agreement may be much lower than for the first one.

We have estimated post-distribution tracking costs on a per-agreement basis. We have assumed above that agreements last, on average, five years and Table 3 shows the number of agreements to be concluded per year. But the five-year duration covers actual exchanges while obligations will typically last beyond this period. Thus post-distribution monitoring will last much longer than the five-year period. Following our reasoning, there would be a build-up in the initial five years of the amount of post-distribution tracking taking place.

For simplicity, we estimate the longer-term average of post-distribution tracking taking place as being based on the number of agreements in existence. These were estimated above and are 5 times the annual number of agreements listed in

Table 3 according to each scenario. We estimate these costs at 10 person-days per agreement per year. For some clonally propagated crop groups investments in following up adherence to PBR and patent regulations by germplasm users equals investments in research and development and varieties (estimated at US$ 1 billion), whereas in other crops groups characterized by hybrid varieties, such follow ups are not necessary because of the nature of the product. Our figure at 2 – 10% of these R&D investments seems reasonable. This figure takes into account the considerable number of samples covered per crop or crop-group agreement (800,000), the high number of yearly released varieties (presently the total number of varieties protected under plant breeders rights according to UPOV amounts to more than 230,000!), and the growing number of patents which include plant germplasm. It also takes into account for a small number of labour-intensive physical tracking cases, sampling and molecular analysis of plants. As can be seen in Table 4, this results in estimates of total post-distribution tracking costs ranging from $0.5 – 1.0 million under a bilateral approach covering only industrial crops (scenario D) to $10 – 50 million under a fully bilateral approach (scenario A). These estimates may seem high but we highlight that we have not included the costs of any legal action against or alternative actions concerning suspected transgressors (reconvening agreement parties, publicity efforts) which while very infrequent will be very expensive.

10. Total Transaction Costs

The total transaction costs for each scenario are presented in Table 4. These totals range from $1.2 – 1.9 million for a MLS including bilateral arrangements covering industrial crops to $ 22 - 128 million for bilateral arrangements covering all crops. There is a difference of more than one order of magnitude between these two extremes, correlating to the number of individual germplasm exchanges involved. Here we note again that the range from lower to higher estimated transaction costs increases in relative terms as the number of crops falling under bilateral agreements expands.

To evaluate what these rather conservatively estimated transaction costs imply, we have to compare these figures with current investments in the maintenance of PGRFA. Such comparison allows us to draw some tentative conclusions about how many bilateral arrangements might actually materialise. In Table 4, we have compared the estimated transaction costs under the various scenarios with the estimated expenditures by private sector breeders on the maintenance of germplasm. These costs are taken from ASSINSEL's Web site, which reports the results of a survey of its members. From this information, which was reconfirmed by an Assinsel representative as realistic, it can be concluded that research and development expenditures of private sector breeders world-wide amount to approximately $1 billion per year and that the portion of this sum allocated to germplasm maintenance is 5%, or approximately $50 million. The range of transaction costs estimated per scenario ranges from 2 - 4 % of these maintenance costs under the most comprehensive multilateral scenario (D) to a level exceeding total current private investment in germplasm maintenance for a fully bilateral approach (scenario A), transaction costs being estimated at 44 – 156 % of these maintenance costs.

From our analysis of germplasm flows it appeared that the public sector is the biggest user of germplasm from genebanks. Moreover, the public sector is the largest investor in maintaining germplasm collections. We, therefore, compared our estimated transaction costs with a rough estimate of public sector expenditures on maintaining genebank collections, as it is out of these budgets that such costs would most likely have to be paid in the first instance. Referring to Burstin *et al.* (1997), we estimated the average annual maintenance costs as $14 per accession.[13] We applied this cost to estimated numbers of accessions coming under the scope of bilateral arrangements in each of our four scenarios.[14] Compared against these numbers, our conservatively estimated transaction costs appear quite significant, ranging from 29 – 101 % of total public investments under scenario A to 14 – 23 % under scenario D. In this respect it should be noted that public budgets for maintenance of PGRFA have been continuously under threat, rendering additional costs a great burden for the public sector and a further threat to the security of germplasm collections.

Assessing whether these costs under any of the scenarios presented might be acceptable for the actors involved is a difficult task. A complete cost-benefit analysis of bilateral arrangements is not within the scope of this paper, as mentioned in the introduction.

The objective of bilateral arrangements, for the germplasm provider, is to capture as much as possible the benefits from the distributed germplasm. Currently it is assumed that predominantly western countries and in particular private breeders capture these benefits. Consequently, one should ask the question what interest public sector users will have in paying such transaction costs and if they will not be inclined to avoid such expenses. Their reluctance to do so may be exacerbated by the financial pressures under which public sector agricultural research institutions are increasingly finding themselves.

A final point of consideration is the estimate of $150 – 450 million required to implement the Global Plan of Action (GPA). For the purpose of our estimates we have set these invesments at $300 million annually. A direct comparison of the estimated transaction costs with the estimated cost of the GPA can be misleading. The GPA includes priority activities for PGRFA conservation and sustainable use, to ensure the conservation of germplasm for the use of future generations, and the unpredictable needs of farmers and plant breeders. Thus, our estimated transaction costs of bilateral arrangements are in no way a substitute for the much broader purposes of the GPA. But the fact that these new and additional public funds have not yet been forthcoming reinforces our scepticism about the acceptability of our estimated additional transaction costs, particularly for public sector stakeholders.

[13] This is based on estimates of $7 for autogamous sexually-regenerated accessions and $43 for vegetatively-propagated accession. We assume that the former comprise roughly 80% of accessions and the latter, 20%. This leads to an estimate of $14 which is somewhat less, but quite comparable, to estimates reported by Virchow (1999).

[14] For a completely bilateral world (scenario A), this is the total 5.5 million accessions currently held. Using data of FAO's State of the World (WIEWS database), the estimate for scenario B is estimated at half of the total (cereals now under the MLS) less the CGIAR-held accessions of 0.6 million, giving an estimate of 2.4 million. For scenario C, we remove a further 0.9 million, corresponding to 16% grain legumes accessions of the total 5.5 million, to arrive at 1.5 million. Scenario D is estimated as covering 10% of the total, leading to roughly 0.6 million.

11. Conclusions

Any study of expected transaction costs under hypothetical scenarios of future developments in institutional arrangements is fraught with difficulties and uncertainties. Indeed, the actual monetary figures produced in such a study are probably not as valuable as the discussion surrounding them as to how they were generated and, more importantly, what they imply for a complete comparison of costs and benefits.

In this spirit, on the basis of our preliminary analysis we conclude that the analysis of transaction costs indicates that a scenario in which all germplasm exchange falls under bilateral agreements entails excessively high transaction costs. These costs would probably drop to more acceptable levels if major food crops were covered by a MLS. The addition or removal of certain crop groups is likely to have a great effect on the transaction costs associated with bilateral exchanges.

Our analysis above has focussed on germplasm exchange patterns and accompanying costs in relation to global investments in the germplasm management for such crops. Whether bilateral exchanges that cover only minor food crops would result in acceptable transaction costs, is still another issue. Minor food crops require generally much more limited germplasm exchange, allowing for less complex negotiating and lower transaction costs under bilateral arrangements. However, these crops also represent a very small component of the commercial seed market if any at all, although they are often of great local and regional importance to food security and culture, justifying germplasm exchange for crop improvement.

We therefore expect that the transaction cost estimates for a scenario with minor food crops covered by bilateral exchanges would be even less acceptable.

Taken together, these considerations push us even more towards the conclusion that bilateral transaction costs may be acceptable only for a very restricted number of crops, e.g. industrial crops, medicinal crops and ornamentals.

If transactions costs are prohibitively high there are two likely resulting effects:

- Exchanges will be restricted as those who might otherwise seek germplasm from foreign sources look for alternative options. Ten Kate and Laird (1999) provide examples based on personal communications of how increased transaction costs caused by bureaucratic complications relating to benefit-sharing arrangements are already discouraging some potential users of germplasm from accessing sources in the South. It is worth emphasising that the cited reluctance to negotiate terms of access and benefit sharing arises from concern about the time and costs of doing so, more than about actual benefit sharing terms. This possibility seems to be supported by a recent press report (O’Connor, Health, Washington D.C., July 2000) stating that even bioprospecting for pharmaceutical purposes under bilateral arrangements has lost a lot of its previous impetus, due to the costs and the negotiating process being prohibitively expensive.

- To reduce overall costs to acceptable levels, activities such as those necessary to track the use of germplasm will be reduced, or benefit-sharing terms agreed to in agreements will be cut back.

Because of total additional costs involved, the exclusion of more plant genetic resources from the MLS will not automatically lead to a proportionate increase in benefits to the germplasm providers. There will be less capturing of benefits than envisaged by those who propose to profit from a bilateral approach.

We also wish to point out that the distribution of gains and losses under bilateral arrangements will probably be quite skewed from a global perspective. A very limited number of source countries might indeed benefit, but at the cost of losses in terms of access to germplasm, improved breeding materials and technology by many more developing and developed countries with limited genetic resources, funds, or existing capacity to use germplasm in national breeding programmes. A considerable number of countries which have limited plant genetic resources for food and agriculture and no breeding products to provide would probably not engage in bilateral agreements, and thus miss the benefits arising from germplasm exchange. These other costs (lack of benefits) are even more difficult to measure and to express in figures, but would certainly have an even greater impact than the transaction costs that form the subject of this study.

While transaction costs are the focus of the discussion here, it is widely assumed that they are only one component of a wider set of opportunity costs involved.

Yet another aspect that is not covered by our conclusions on prohibitively high and uneven distribution of transaction costs, and the benefits of bilateral exchange arrangements relates to the uneven distribution of negotiating power and capacity between many demanders of PGRFA including private sector breeders (whether located in the North or the South) and northern public sector institutions, and many of the South-based suppliers. Also on this grounds it can be questioned whether envisaged benefits will be realised.
Finally, we would like to emphasise again that both parties developing an agreement to exchange germplasm would incur transaction costs. Such agreements would not generate new benefits but potentially redistribute existing benefits. The central question is whether a MLS with wide coverage can not offer a better mechanism to redistribute the existing benefits in an equitable way against less costs.

12. References

ASSINSEL. http://www.worldseed.org/

Brush, S.B. 1998. Bio-cooperation and the Benefits of Crop Genetic Resources: the Case of Mexican Maize. *World Development* 26(5): 755-766.

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

Evenson, R.E., D. Gollin and V. Santaniello (Eds). 1998. *Agricultural Values of Plant Genetic Resources*. CABI, Wallingford, UK.

Fowler, C. and M. Smale. 2000. Germplasm flows between developing countries and the CGIAR: an initial assessment. GFAR Initiative on Genetic Resources for Food and Agriculture micropaper. FAO/IPGRI, Rome, Italy.

IPGRI. 1996. *Options for access to plant genetic resources and the equitable sharing of benefits arising from their use*. Issues in Genetic Resources, No. 5. IPGRI, Rome, Italy.

Ten Kate, K. and S. Laird. 1999. *The Commercial use of biodiversity: access to genetic resources and benefit-sharing*. Earthscan, London, UK.

Virchow, D. 1999. *Conservation of Genetic Resources: Costs and Implications for a sustainable utilization of plant genetic resources for food and agriculture*. Springer, Berlin, Germany.

Table 1: Overview of germplasm flow for selected crops

Crop	Genebank	Number of distributed accessions [1]	Number of source countries of material[2]	Number of destination countries	User types (%)					User geography (%)	
					CGIAR centers	NARS Universities Genebanks	NGOs	Private sector	Others	OECD	non-OECD
Wheat	SINGER	22,601	65	39						25	75
Wheat	CGN	3,187	89	23	3	27	3	66	1	95	5
Wheat	NGB	1,881	6	35	1	35	0	64	0		
Wheat	USDA	62,851	31	58							
Wheat	NIAR	17,186	72	55	0	96	0	0	4		
Barley	SINGER	26,845	83	34						38	62
Barley	CGN	1,603	69	18						95	5
Barley	NGB	3,352	8	39	1	25	0	74	0		
Barley	NIAR	9,507	57	64	5	86	0	0	9		
Pearl Millet	SINGER	103	17	25	32	51	1	0	16	5	95
Rice	SINGER	154,563	108	106	57	41	<1	<1	1	11	89
Rice	NIAR	21,453	77	31	6	76	0	0	18		
Sorghum	SINGER	49,482	82	98	15	75	<1	5	5	15	85
Phaseolus	SINGER	22,270	88	74						20	80
Phaseolus	NGB	70	4	11	0	31	0	69	0		
Chick pea	SINGER	56,039	59	92	47	42	<1	<1	10	4	96
Cowpea	SINGER	406	29	30	27	69				55	45
Groundnut	SINGER	29,774	88	96	56	40	<1	<1	4	1	99
Pigeon pea	SINGER	22,517	70	107	58	38	<1	1	3	2	98
Banana	SINGER	1,881	7	54						39	61
Potato	SINGER	3,964	16	103	8	82	1	2	7	21	79
Potato	CGN	917	11	12	0	66	0	26	8	93	7
Sweet potato	SINGER	139	17	9	4	80	0	0	16	6	94
Sweet potato	NIAR	936	28	7	0	53	0	0	47		
Brassicas	CGN	4,164	53	28	0	57	3	36	4	92	8
Lettuce	CGN	10,824	59	24	0	62	1	37	0	93	7
Lettuce	NGB	35	2	6	0	51	0	49	0		

Crop	Genebank	Number of distributed accessions [1]	Number of source countries of material [2]	Number of destination countries	User types (%)					User geography (%)	
					CGIAR centers	NARS Universities Genebanks	NGOs	Private sector	Others	OECD	non-OECD
Pepper	CGN	345	103	10	0	50	0	43	7	77	23
Tomato	CGN	375	62	14	0	69	0	30	1	65	35
Tomato	NIAR	1,269	49	21	0	95	0	0	5		
Tomato	NGB	13	1	6	0	8	0	92	0		
Grasses	SINGER	460,310	154	97	36	58	<1	3	3	15	85
Grasses	NGB	2,132	7	26	0	21	0	79	0		
Grasses	NIAR	3,093	>37	>11	0	100	0	0	0		
Total		933,236									

Notes
1. Figures from SINGER cover from 1990 onwards; those from CGN, from 1985; those from the Nordic Gene Bank, from 1975; those from USDA-ARS (GRIN) from 1990 on foreign exchange only; those from NIAR, Japan from 1986, foreign exchange only.
2. Source countries refers to sources of all accessions for each crop in the collections of genebanks, not necessarily just to the distributed accessions, exceept fro USDA-ARS where figures on source countries only cover incoming germplasm since 1990; the number of source countries is thus a maximum number of sources, except in the case of the USA.