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ECONOMIC VALUATION OF BIOLOGICAL DIVERSITY

Note by the Secretariat

1. Introduction

1. Decision II/11 of the second meeting of the Conference of the Parties (COP) requested th Executive Secretary to compile an annotated list of studies and other relevant information on th social and economic valuation of genetic resources, including the demand by industry for genetic resources. This decision also requested the Executive Secretary to further elaborate the survey of measures taken by governments to implement Article 15, including national interpretations of key terms used in that Article, with a view to completing the survey in time for circulation at the third meeting of the COP.

2. Item 12.1 of the provisional agenda for the third meeting of the COP (document UNEP/CBD/SBSTTA/2/Inf.10) indicates that this meeting may consider "the compilation of views of Parties on possible options for developing national legislative, administrative or policy measures to implement Article 15".

3. In response to the COP's intention to explore the ways and means of implementing Article 15, the SBSTTA, in its mediu -term programme of work for 1995-1997 (document UNEP/CBD/COP/2/5, recommendation I/2), decided that it would consider the provision of scientific, technical and technological advice on the economic valuation of biological diversity and its components, in particular in relation to access to genetic resources.

4. To assist the SBSTTA in its consideration of this item, the Secretariat has prepared this Not on the economic valuation of biological diversity, with a particular emphasis on the valuation of genetic resources. The Note briefly recalls the need for the economic valuation of genetic resources within th

Convention and then reviews the existing literature. The Note concludes with some observations about possible advice and recommendations that the SBSTTA may wish to consider under this item of th provisional agenda.

2. Background

5. Economic theory holds that in order for any resource to be properly managed, the cost of using the resource needs to reflect all the values that society places upon it, social and economic, including the costs of the external effects associated with exploiting, transforming and using the resource, together with the costs of future uses forgone. In econo mic parlance this means internalising th external benefits and costs, known as externalities, associated with using a resource. Failure to properly value resources means that incorrect signals are sent to decision -makers, conveying, in turn, misleading information about the resources' scarcity and thus providing inadequate incentives for th management, efficient utilisation and enhancement of living resources.

6. It is widely acknowledged that the current use of biological resources is both inefficient an d inequitable due to the fact that there is a gap between the private and social values of biodiversity. There are many causes for this gap, such as: (a) ignorance or uncertainty over the social consequences of private actions; (b) a structure of rights that encourages people to ignore the known social consequences of their actions ("tragedy of the commons"); and (c) government policy that fails to correct externalities and can worsen things (policy failure). These market and policy failures are, according to economists, the main underlying causes of biodiversity loss (Perrings 1995).

7. Economists often describe the range of benefits that biodiversity provides as set in Table 1.

Table 1. Total Economic Value of biological resources.

	USE VALUE		**+**	**PASSIVE OR NON-USE VALUE(1)**
DIRECT + VALUE	**INDIRECT + VALUE**	**OPTION + VALUE**	**(QUASI + OPTION VALUE)**	**EXISTENCE VALUE**
Provision of basic resources: food, medicine, construction materials, nutrients.	Providing support for economic activity and human welfare, e.g. watershed protection, waste storage and recycling, maintenance of genetic diversity and erosion control. Providing basic resources: e.g. oxygen, water, genetic resources.	Preservation o future direct and indirect use values		
Non-consumptive uses: recreation			Conservation of yet unknown future uses	Forests as objects of intrinsic value, as a bequest, as a gift to others, as responsibility (stewardship). Includes cultural, religious and heritage values.
Plant genetic resources	Providing information benefits such as scientific knowledge.			

***Source**: Pearce, D.W. 1990. An Economic Approach to Saving the Tropical Forests. LEEC Paper DP 90-06. IIED, London; and Perrings (ed.) 1995. The Economic Value of Biodiversity, in Heywood, V.H. 1995, Global Biodiversity Assessment, UNEP, Cambridge University Press, UK.*

(1) **Passive use or non-use** value is the value that individuals place on biological resources that they do not intend to use, but would feel the "loss" of if they were to disappear. Notes: **Direct Value** refers to those benefits that can be observed being consumed, although their consumption might not yield a meaningful price that can b assigned to that benefit. **Indirect Value** refers to those benefits that are not observed being consumed, but that are known to be essential to the preservation and maintenance of ecosystems. **Option Value** is the value placed on securing the futur consumption of goods and services yielding direct and indirect valu . **Quasi-Option Value** is the value of learning about future benefit s that would be precluded by development or irreversible change of the forests today. This takes into account th fact that current valuations are circumscribed by current knowledge of forest functions. **Existence Value** is that value placed on an environmental asset independent of its current or future "usage". This incorporates the innate value of the forest *in situ*.

8. In the case of biological diversity the value of the intangible benefits (indirect value; option value; quasi-option value and existence v alue) is significant. Valuation and methodologies for evaluating the benefits of biological diversity at the species and ecosystem level are rapidly evolving. recent and relatively comprehensive assessment of this area is provided in the Global Biodiversity Assessment (Perrings 1995).

9. Contemporary understanding of the benefits of genetic diversity and the value of the benefits that genetic resources provide is not so well appreciated. This is due to two main reasons: (a) that it is the least-known lev l of biodiversity and consequently our understanding of the resources is poorer than for other manifestations of biodiversity; and (b) estimating the value of the benefits of genetic diversity poses many extra methodological difficulties compared with undertaking a similar exercise for other aspects of biodiversity. This arises because the principal direct economic value of genetic diversity is the information that it represents. Measuring this benefit, as with other intangible benefits, has always been pro blematic because what is required is not a calculation of an easily measured consumptive process, but the value of the information that the resource brings to the production process. As this will often be only one of many sources of information required to develop the process, and often not even the most important source, assessing the proportion attributable to the natural genetic resources is not straightforward. Thus, what is being measured in this process is not the market for herbal remedies, but the value of the contribution that a natural biochemical makes to developing a new drug or a new crop variety. As there is no well-established methodology for estimating this type of contribution, it is largely dependent upon the subjective values of those making the assessment. Work on estimating other benefits of the value of genetic diversity (such as its indirect, option and existenc values) is almost non-existent.

10. The agricultural, pharmaceutical, and horticultural industries have always relied upon ac cess to "new" genetic resources as a source of innovation. Recent developments in biotechnology are not only increasing demand in these traditional markets, but also opening up new applications and markets for genetic resources. For example, there is a rapidly increasing demand for genetic resources fro

exotic bacteria found in extreme environments, known as "extremophiles"; an issue considered in some detail in document UNEP/CBD/SBSTTA/2/15.

11. Due to the magnitude of the global benefits derived from the use of genetic resources, their internalisation provides an important opportunity for ensuring sustainable use, the equitable sharing of benefits and, ultimately, the conservation of biodiversity. The Convention recognises the importance of using genetic resources as a means of achieving its goals. Article 15 provides a legal basis by which countries can assert ownership and control over these resources and thereby begin to internalise th externalities that currently exist.

12. In order to effectively imp lement the Convention's provisions with regard to the use of genetic resources, it is imperative that a reasonably accurate and reliable method (or methods) of evaluating these benefits be developed. At the moment there is only anecdotal evidence that genetic resources ar valuable on a global basis. It is by no means clear how much particular countries or communities benefit or lose under the current regime. Neither is it clear which countries stand to gain or lose if th current situation is changed. Det rmining this is important because the benefit flows of genetic resources are complex, interrelated and very international. For example, the high level of interdependence in crop development meant that some of the genes that made a significant contribution to the Green Revolution came from the natural genes found in developed countries (Kloppenburg 1988). If mechanisms were established to internalise this international externality then developing countries would be compensating developed countries.

13. More specifically, knowing or being able to measure the economic value of genetic diversity is vital in order to properly implement many important elements of the Convention. The experience to date has been that contractual arrangements, or what have been described as Access and Benefit Sharing (ABS) Agreements, between the provider of genetic resources and those wishing to use th genetic resource have been the most common mechanism for endeavouring to implement the principles of the Convention. In the absenc of some reliable method for estimating the value of genetic resources, the price received by the provider is largely determined by market practice. Given the lack of experience and precedent in many of the markets for genetic resources, it is unlikely that the value thes markets give to the resource will reflect the full value placed on it by society. The experience in other markets for primary or raw materials is that rarely, if ever, do the suppliers receive optimal value for the resource. Indeed, given the circumstances of most of these ABS Agreements, with a large multinational company on one side and an individual collector on the other, it is most likely that th price received by the collector will be significantly less than the optimal price required to send the right signals to managers of these resources.

14. In an effort to obtain a better return for genetic resources many providers have started to negotiate rights to royalties over future profits from any product that relies on genetic material. From the viewpoint of the provider, determining the optimal balance between the immediate return -- in the form of the up-front f -- and the future return -- in the form of the rate of the royalty -- is not really possible without some understanding of the value of the genetic material. Even calculating what is a fair royalty is difficult without this basic type of information.

15. There are many other more fundamental questions surrounding the use of genetic resources and the implementation of the principles of the Convention that will rely to some extent on being able to understand the economic value of that use. Although the Convention provides that the benefits of th use of genetic resources be shared equitably, it provides little by way of specific detail as to how this is

to be achieved. Guidance of some sort will be required to ensure that benefits are shared properly. Questions such as:

(i) What is "fair and equitable"?

(ii) What are the nature of such benefits?

(iii) What mixture of different benefits are appropriate for different uses of genetic resources?

(iv) How should benefits be shared?

(v) What type of mechanisms are to be preferred in identifying stakeholders and in channelling benefits back to local and indigenous peoples?

(vi) Who are the beneficiaries?

(vii) How should unidentified beneficiaries' or future generations' interests be taken into account?

(viii) How should retrospectivity be dealt with?

will all depend to some extent on being able to develop a reliable method for economically evaluating the benefits of genetic resources.

16. Controlling access to genetic resources has, in other fora, proven to be a controversial and divisive issue. This is due largely to differing expectations about the value of genetic resources. Th absence of reliable facts and figures, or of a sound understanding of the economic value of genetic resources, has allowed rhetoric and politics to dominate the debate in some fora, making progress difficult. These tensions may well arise in any consideration that the Convention gives to the issue. Consequently, progress in implementing Article 15 may well be difficult without reliable information about the economic value of genetic resources.

17. Many other important provisions of the Convention are dependent upon a reliable methodology for estimating the value of genetic resources. For example:

1. Given the increasing preference for market-based policies around the world, integrating the conservation and sustainable use of biological diversity in relevant sectorial or cross-sectorial plans, programmes and policies will rely significantly on being able to assign an economic value to all aspects of biological diversity, including genetic resources;

2. Developing and implementing the requirements of the Convention with regard to environmental-impact assessment procedures will similarly depend on being able to assess th economic importance of genetic diversity.

3. Identifying the important components of biological diversity as required by Articl 7 will be dependent on being able to measure the economic value not only of ecosystems and species, but also of genetic diversity. Indeed, Annex 1 of the Convention, which gives an indicative list of the important aspects of biological diversity, mentions several aspects that ar heavily dependent on being able to make some assessment of the economic value of genetic diversity. For example, it specifically indicates that regard should be given to genomes and genes that are of economic value. It also mentions the species of medicinal, agricultural or other economic value that are of importance. Assessing whether a genome or species is of

importance in these categories will manifestly depend on being able to measure the value of genetic diversity.

18. An ability to measure the value of genetic diversity is similarly important for properly: implementing Article 8(j), along with its sister provisions of Articles 10(c) and 18.4; understanding how intellectual property rights may have an influence on the implement ation of the Convention as required by Article 16(5) and decision II/11 of the COP; implementing Article 19 on the handling of biotechnology and the distribution of its benefits; developing incentives in accordance with Article 11; and adopting measures that avert or minimise adverse impacts on biological diversity in accordanc with Article 10(b), to name but a few. Without a more developed understanding of the values of genetic diversity, or the methodology to make such an evaluation, it is not only difficult to determine the right mechanisms for implementing the provisions of the Convention, but it might also lead to a situation where well-intentioned measures actually result in some developing countries being worse off than under the existing regime.

3. Biodiversity as an input into the research and development process

19. The major focus of the research carried out on the value of genetic resources has been on their use in the pharmaceutical and agricultural industries, which use genetic diversity as a source of information in their development of new products.

20. Economists have long analysed the research and development process as one of information utilisation, application and diffusion (Arrow 1962; Nordhaus 1969). The concept of research and development is usually presented as a production process itself dependent upon a stock of "information" for its generation of useful innovations (Stoneman 1983).

21. The information that genetic diversity represents may be brought into commercial use in one of three ways: the information contained in a genotype may be transferred to the desired end directly (i.e., through transferring genetic material), traditionally through breeding and hybridisation between closely related organisms, and more recently through novel technologies of gene transfer; the information can be exploited directly through the expressed phenotype of the organism, so that new organisms ar brought directly into commercial production; and the information may be used to develop new products without translocating the biological material.

22. Pharmaceutical industries most often pursue the third of these means (making use of observed strategies in biological material), while agricultural industries most often pursue the first (Swanson 1995). For example, pharmaceutical companies screen diverse life forms in order to ascertain th presence of chemicals with biological activity (e.g. "alkaloids" in plants) (Fellows 1995). If this information is identified as having some useful potential, then the p harmaceutical industry will, within a laboratory environment, usually focus on the synthesis of that activity from basic chemical constituents (Albers-Schonberg 1995). On the other hand, agricultural and plant-breeding companies have, in the past, operated almost exclusively through the identification of useful traits within closely related organisms and the selective breeding for the transport of those genotypes into a particularly useful strain (Orians et. al. 1988). Although the two industries are pursuing the same basic object (i.e., the incorporation of successful biological strategies into the human economic system), they us contrasting techniques to effect this endeavour. Both industries make limited use of the second of thes means -- the introduction of new organisms directly into the production process. This is also employed with some frequency by the horticultural industry.

23. The importance of biodiversity for these industries is that living systems must contain a library of such successful strategies. The manner in which such strategies are imported into production systems is not really crucial, except to the extent to which existing techniques limit the transferability of the information contained in biological diversity. At present, the technological frontier in this region of human industry is expanding rapidly, resulting in declining constraints on the transferability of this information. It is now possible to transfer strategies between organisms and living systems in ways that were not imaginable a few years ago. Consequently, the expansion of the technological frontier should dramatically increase, rather than reduce, the value of genetic diversity in the research and development process.

3.1 Empirical evidence of the value of genetic diversity in the pharmaceutical industry

24. The medicinal value of plants and their derivatives has been recognised for millennia. Traditional medicine has evolved by taking advantage of the genetic information in wild plants, selecting those that have developed characteristics that make them effective against human diseases. The informational value realised through the direct use of wild products is still very important in th developing world. It is estimated that some 80% of the people in the rural developing world rely chiefly on herbal medicines for their primary health care needs (Farnsworth and Soejarto 1991; Hamann 1988, both cited in Lewington 1993; Falconer 1990, for West Africa). These traditional systems typically rely on a wide range of species. In Chinese medicine alone, it is estimated that 80% of medications come from some 5,000 higher plants (Farnsworth and Soejarto 1991; Hussain 1991, cited in Lewington 1993). While these data do not indicate the relative importance of individual species, it is clear that traditional medicine relies on a wide diversity of natural products. Specific studies in Western Africa and Asia have identified between 70 and 200 plant species currently used by individual communities (Falconer 1990; Elliot and Brimacombe 1985, in Sayer 1991; Levy-Luxereau 1972, in WCMCe 1992). Worldwide, it is estimated that some 10,000 different species are used by at least on community for medicinal purposes (Fellows 1991 in Lewington 1993). Despite the apparent value in current applications of biological resources, estimating the importance and economic value of th biodiversity that gives rise to the possibility of more discoveries is a very recent field of interest.

25. In order to assess the value of biodiversity in the pharmaceutical industry, it is necessary to trace its input to the research and development process. A number of studies have recently been conducted that try to place a value on the genetic diversity in nature, based on the possibility of finding valuable information for the development of future pharmaceuticals. Table 1 presents a summary of these studies.

Table 1. Summary of the Literature on the Pharmaceutical Value of Biodiversity

Reference	Farnsworth and Soejarto (1985)	Principe (1989b)	McAllister (1991)	Principe (1989b)	Ruitenbeek (1989)	Harvard Business School	Pearce and Purosho-thaman (1992)	Simpson et al (1993)	Alyward (1993)	Fernandez (1994)	Reid et al (1993)
Biodiversity valued	plants	plants	trees	plants	Cameroonian species	Costa Rican species	rainforest plants	plants	plants	plants	biotic samples
Scope of values	US	OECD	global	OECD	not specified	not specified	OECD	not specified	US/Costa Rica	not specified	not specified
Type of data	drug sales	drug sales	drug sales	value of life saved	patent renewal costs	royalties on drug sales	drug sales and value of life saved	required net revenue from prospecting to create a land value of US$1/ha	net returns from prospecting	net return from prospecting for a single drug	royalties on drug sales
Type of value	annual	annual	annual	annual	annual	NPV	annual	NPV	NPV	NPV	NPV
Value per item (US$m)	200	200 US 600 OECD	0.25	37,500	7.5	0.253	1.95 - 350	197-19,887	40-459	40-459	not specified
Success rate for discovery of new drugs	1:250	1:2,000	3:100	1:5,000	not specified (10:500)	1:10,000	1:1,000 or 1:10,000	1:n+1 (4)	1:10,000	1:10,000	1:40,000
Value per untested species (1991 US$)	2,580,000	474,000	7,500	23,700,000	15-150	253	585-1,050,000		21 (1) 166 (2) 233 (3)	Industry will screen up to 29,040 if samples are free or 15,700 if US$50 per sample.	52-46,000,000

Expanded from Alyward (1993) incorporating the results of Simpson (1993) and Fernandez (1994).
(1) per biotic sample in private cost scenario
(2) per species in social cost scenario
(3) per biotic samples royalty model
(4) n is the collection of species

26. There are, however, methodological problems with all of these studies. Vogel reviewed many of the studies referred to in Table 1 and concluded that even "the most comprehensive and thoughtful treatment" (Alyward 1993) was "so sensitive to a few key assumptions that the conclusions h [Alyward] reaches, □he returns from pharmaceutical prospecting cannot be expected to generate a "market solution" to the biodiversity crisis’, could easily be reversed". The key assumptions that Vogel identified were: the royalty rates chosen; the "hit rates" for bioactivity; the overall volume of biodiversity; and the diffusion of secondary compounds across habitats. Vogel applied the model developed by Alyward to estimate the value of Ecuador's genetic resources for use by the pharmaceutical industry and came up with a national value of $256 million. He then applied a series of quite plausible alternatives for each of the key assumptions used in Alyward□ model and was able to come up with a figure of $429 billion. He observed, in an abstract of his book, that "[b]oth estimates

teeter on a scaffolding of assumptions, all of which are defensible but may nevertheless turn out to b very wrong with hind sight. What will be the criterion of the Ecuadorian politician to decide. Th bilateral $256 million or the multilateral $429 billion? The cynical answer is politics. For example, when timber interests are strong, the former will be cited as justification for the status quo, when environmental interests are strong the latter will be quoted long after the evidence has emerged to correct what turned out to be a false assumption".

27. Confirmation of Vogel's observations are found in the widely varying estimates given in th table of the economic value to the pharmaceutical industry of raw natural genetic material.

28. Even defining the extent of the contribution attributable to the information from naturally occurring genes has proven problematic in the literature. In a recent survey (Olsen et al. 1996), "Natural products research" (NPR) was found to be an important part of the research strategy of every pharmaceutical firm. For the large, vertically integrated firms, this typically amounts to 5% to 20% of the total research and development budget. About on -third of the firms taking part in the survey wer small, specialised companies focused on collecting and screening; these firms expend a far greater proportion of their budgets on NPR, but it is a small part of total industrial expenditure. In this survey most companies stated that expenditure on NPR had recently been increasing.

29. The primary reason cited for the recent expansion of NPR activity was the declining cost of screening activities. The speed at which samples may be screened has increased by a factor of on hundred in the past decade, due to the efficient automation of screening techniques. Numbers of possible screenings now range from 300 plant species per year for a small specialist company, to hundreds of thousands of specimen s (natural and synthesised) by a large generalist. Despite this development, other stages in research and development activities increase the cost of NPR, namely, th time and expense required to structurally elucidate the relevant portions of the molecule, i.e., to separate out and identify the precise chemical structures supplying the biological activity. This process was estimated to require, on average, 4 to 5 additional years to complete, and an additional $60,000 in development expenditure. Another more crucial factor discriminating against natural products was th critical necessity of an assured future supply. If the additional costs of natural -product development were to be undertaken (estimated at $200,000 in time and funds), then there must be a certainty of future flows of the resource required.

30. The asserted alternative to NPR was the modification of known active structures, and th screening of them once synthesised. These synthesised molecules were far more likely to be subject to massive l vels of screening, as the cost of screening was low and the costs of subsequent development would be essentially zero (until clinical trials). In terms of sheer volume, synthesised molecules are th primary focus of research and development activity, but it is acknowledged throughout the industry that the templates for these compounds, and the vast numbers of permutations upon them, must always come from nature. Nature is the provider of complex active molecules, but these must be simplified in order to guarantee both understanding and future supplies.

31. It would therefore appear that virtually all research and development in the pharmaceutical industry has, to some extent, its source in naturally generated information. Confusion on this point emerges by reason of the specificity with which the industry has defined the term "Natural Products Research"; this term focuses on developing physical material within biological organisms directly into medicinal products (so-called "silver bullets"). Pharmaceutical c ompanies usually disparage NPR for the expense of either: a) developing biological material into synthetic material; or b) procuring secur supplies of biological material across time. Given this narrowly defined role for natural products within

the industry, it is not surprising that NPR is found to be only a minor portion of research and development.

32. It is very seldom that nature provides such a ready-packaged molecule, already purified and isolated for its impacts on the human species (although many pharmaceutical compounds now in us derive from about 40 such substances). More often, the value of biological material lies in its mor generalised but equally fundamental information, which must then be further refined and developed. It seems that the vast majority of screened molecules are of this onc -removed nature, derived fro human modifications of natural templates. Literally hundreds of thousands of permutations may b built upon the foundation of a single template, and so synthesised substances are seen as being the focus of the screening industry. The fact remains that the raw material for this enterprise comes initially from natural templates. A proviso must be added in that there are some pharmaceutical companies that claim that it is now possible to produce wholly "rationally designed" pharmaceutical drugs. This is sometimes argued to represent a new independence from nature, although a complet shift to such products seems a remote possibility in the foreseeable future.

33. A wider understanding of what NPR entails leads to the conclusion that biological diversity is a crucial factor in the production of modern medicine, even though the industry itself recognises its contribution only in cases where it works most directly and completely. It appears that naturally generated information has had at least some role in the creation of virtually every pharmaceutical to date, and continues to provide the templates for current research.

3.2 Empirical evidence of the value of genetic diversity in agriculture

34. Plant breeders are constantly investigating the closest relatives of the small number of domesticated species to ascertain their potential for contributing to the productivity or resilience of th domestic varieties. This process of applying genetic techniques has had increasing application to and effects on the world's agricultural production. The Green Revolution, which brought a rapid increase in wheat and rice yields in developing countries, was fuelled by the use of improved seed varieties and the application of fertilisers and other chemical inputs. These have made high-yield crop varieties comparatively more profitable than other traditional grains and vegetables, and as a consequence th area sown with improved seed has increased dramatically.

35. The success of the high-yield varieties is indicated by the speed with which they have spread across the developing world. It has been estimated that between on -third and a half of the area devoted to rice in developing countries is now sown wi th them. CIAT (the International Centre for Tropical Agriculture, Colombia) estimated, for example, that in the mid-1980s high-yield varieties were grown on 90% of the 3 million hectares devoted to rice in Latin America. At present, nearly all modern crop varieties and some highly productive livestock strains contain genetic material recently incorporated from related wild or weedy species, or from more primitive genetic stocks still used and maintained by communities that practice traditional agricultural.

36. The combined economic value of the improvements in agricultural techniques has been significant in many parts of the world. In upland rice areas, for example, CIAT (1981) estimates that yield increases are between one ton/ha on irrigated areas and 0.75 tons/ha. This constitutes an annual increase of about 2.75 million tons of rice, which at an average price of $200/ton is an increase in th value of production of approximately $550 million. It has been estimated that at least half of th

increase in agricultural productivity realised this century is directly attributable to "artificial selection, recombination and intraspecific gene transfer procedures" (Woodruff and Gall 1992).

37. A considerable amount of work has been carried out in estimating the often substantial value of genetic improvements to crops. Some of the more important studies are summarised in Table 2.

Table 2. Genetic diversity and agriculture: genetic contributions of cultivars to crop yields

CROP	**LOCATION**	**PERIOD**	**EFFECT ON PRODUCTION**	**SOURCE**
All crops est.	USA	1980s	$1.0 billion/year	OTA, 1987, USDA
Maize	USA	1930-80	2 of a four-fold increase in yields	OTA, 1987 USA
	1930-80	89% of yield gain of 103 kg/ha/yr	in commercials	Duvick, 1984
	USA	1930-80	71% of yield gains in singl -cross hybrids	Duvick, 1984
	USA	1985-89	Genetic gains to N. Dakota of $2.3 million/year	Frohberg, 1991
Rice	Asia	GR	$1.5 billion/year	Walgate, CALP
	USA	1930-80	2 of a doubling in yields	OTA, 1987 Wheat
	Asia	GR	$2.0 billion/year	Walgate, CALP
	USA	1930-80	2 of a doubling in yields	OTA, 1987
	USA	1958-80	0.74% genetic gain per year - 2 of 32% yield gain	Schmidt, 1984
	UK	1947-75	50% of an 84% gain in yields	Silvey, 1978
	World	1970-83	43% of genetic gain totalling 46% (best data)	Kuhr *et al.*, 1985
			55% of genetic gain totalling 32% (all sites)	Kuhr *et al.*, 1985
Sorghum	USA	1930-80	2 of a four-fold increase in yields	OTA, 1987
		1950-80	1-2% genetic gain per year from manipulating kernel numbers, plant weight, height and leaf area	Miller and Kebede, 1984
Barley	USA	1930-80	2 of a doubling in yields	OTA, 1987
Potato	USA	1930-80	2 of a four-fold increase in yields	OTA, 1987
Soybeans	USA	1930-80	2 of a doubling in yields	OTA, 1987
	USA	1902-77	79% of 23.7 kg/ha annual yield gains	Specht and Williams, 1984
Pearl Millet	India	at present	genetic improvements worth $200 million annuall	ICRISAT, 1990
Cott	USA	1930-80	2 of a doubling in yields	OTA, 1987
		1910-80	0.75% genetic gain per year	Meredith, Jr and Bridge, 1984
Sugar cane	USA	1930-80	2 of a doubling in yields	OTA, 1987
Tomato	USA	1930-80	2 of a three-fold increase in yield	OTA, 1987

38. The aggregate value of the raw genetic materials used in crop-breeding can also be ascertained by reference to the industry's spending on research and development. This is because, as with so many of the facets of biodiversity, the value of genetic variety for crop breeding lies in the potential value of future finds from the existing genetic stock. An indication of this value is given by the returns realised from past efforts at developing the previously existing gene pool for commercial use, as well as by th amounts currently being invested in such efforts.

39. The top 25 agricultural biotechnology -- or crop-breeding -- firms spent $330 million on research and development in 1988 (Hobbelink 1991). Crop breeding has generated a large return in th past -- US public and private expenditures on corn research totalled $100 million in 1984, contrasted with an estimated return of $190 million (Huffman and Evenson 1991). Such investments serve to pay for the development of both successful and unsuccessful varieties. It is estimated that, on average, 75% of new varieties recoup research and development costs (Olsen et al. 1996).

40. These figures indicate that the plants that are most closely related to our domesticated crops provide enormous benefits. Several important examples are given in Table 3. These varieties repres nt only a fraction of existing genetic diversity, but are probably some of the most valuable species on account of the ease of their introduction into mass production.

Table 3. Genetic diversity and agriculture: specific contributions made by wild relatives of crops

Crop	**Found in**	**Effect on productio**
Wheat	Turkey	Genetic resistance to disease, valued at $50 million per year
Rice	India	Wild strain proved resistant to the grassy stunt virus
Barley	Ethiopia	Protects California's $160 million per year c rop from yellow dwarf virus.
Beans	Mexico	Genes from the Mexican bean used to improve resistance to the Mexican bean weevil, which destroys as much as 25% of stored beans in Africa and 15% in South America.
Grapes	Texas	Texas rootstock used to revitalise the European wine industry in the 1860s after a louse infection.

Source: WCMC (1992)

41. For several reasons, however, the calculated valu -gains from crop-breeding efforts are not equivalent to the value of the raw genetic material that exists in th wild. Such gains, for example, may be achieved using raw materials from a variety of sources: existing cultivated varieties (cultivars), varieties husbanded by traditional farmers (landraces), wild relatives of crops, or even -- with the advent of genetic engineering -- completely unrelated species. Furthermore, these gains must be apportioned among a number of factors that, together with these raw genetic materials, generate this increased value, including scientific effort, technology and commercial development.

42. Evaluating the sources of germplasm is a complex issue given the fact that once wild genetic material is incorporated into existing varieties, only the new variety has to be accessed in the future in order to develop further varieties. In other words, the contribution of wild genetic material is constantly reused although this is not reflected in the sources of germplasm. Table 4 shows the results of a survey of plant breeders about their sources of germplasm.

43. The sources of germplasm range from the already heavily exploited cultivars to completely wild species, to technologically altered species (biotechnology and induced mutation). Table 4 demonstrates that, averaged over a fiv -year period, 6.5% of all "successful" genetic research (i.e., research resulting in a marketed innovation) within the agricultural industry was focused on germplas from relatively unknown species (wild species and landraces); 3% of such genetic research was directed to the transference of traits into the commercia l system from wholly wild species.

Table 4. Source of germplasm used for all development of new varieties.

CROP GROUP

Source of Germplasm	All	Potatoes	Cereals	Oil	Vegetable
Commercial cultivar	81.5	50.0	87.0	78.8	95.7
Related minor crop	1.4	8.0	0.6	1.2	0.3
Wild species - *ex situ* gene bank	2.5	19.0	1.2	1.0	1.4
Wild species - maintained *in situ*	1.0	0.0	0.7	0.1	0.1
Landrace - *ex situ* gene bank	1.6	1.7	1.7	2.3	1.7
Landrace - maintained *in situ*	1.4	0.0	0.7	2.8	0.4
Induced mutation	2.2	3.3	0.7	7.2	0.3
Biotechnology	4.5	17.7	3.5	6.8	0.1

Source: WCMC 1994. (Note that all columns are percentages, but that not all columns sum to 100% as some innovations defied categorisation under a single source). ["related minor crop": minor crop cultivated on a small scale with some improvement over wild ancestors*

44. One other important indicator derived from the table is the extent to which substitutes exist for external supplies of new germplasm. There is only one alternativ at present: induced mutation. This technological approach to generating diversity supplies about 2.2% of new germplasm, approximately one-third as important as natural sources. The other important contributor, biotechnology, is not so much a substitute for natural diversity as it is a method for transferring characteristics across greater distances (i.e., between less closely related species). New biotechnological methods for transporting germplasm provide about 4.5% of all germplasm, but it is very likely that biotechnological research relies upon natural diversity to the same extent that general agricultural research does.

45. The value of the wild species multiplies if the dynamic nature of the battle against pests is considered as well. For example, Chang (1989a, in Evenson 1995) reports that while resistance to whitebacked planthoppers was found in only 0.8% of the 48,544 varieties of *Q. sativa* screened at IRRI, it was found in 46.2% of the 437 wild *Oryza* species tested. While the development of a particular pest resistance can take a decade, it can take as little as 4 or 5 years for the resistance to "break down" as pathogens and pests evolve far more quickly (Olsen et al. 1996), thereby creating th need for the continuous development of new varieties.

46. Evenson (1995) calculated a breeding production function for rice that allows for an estimat of the role of the size of the crop genetic resources entering the research and development process. According to his results, the increase of catalogued accessions from around 20,000 to 60,000 between 1960 and 1995 has been responsible for 20% of the gains in yield. These estimates suggests that each additional rice genetic resource accessions adds, on average, between US$2,500 to US$5,000 per year in perpetuity. The present value of this stream, assuming a ten -year lag -- the time needed to develop and market a variety -- and a 10% discount rate is $10,000 and $20,000 (Evenson 1995).

4. Conclusion

47. The existing literature clearly demonstrates that genetic diversity is the source of considerabl wealth and, consequently, is extremely valuable.

Advice on the economic valuation of biological diversity is of general relevance to the thr -fold objectives of the Convention and, as a consequence, any recommendations made by the SBSTTA can be of relevance to other items to be considered by the COP, including items 6, 7, 9, 12 and 14 of the provisional agenda. For example, item 12 is to consider the possible options for implementing Articl 15 on access to genetic resources. Clearly, developing effective strategies will depend on an understanding of the economic value of these genetic resources.

48. The research carried out so far has been *ad hoc* and suffers from a lack of rigorous and reliable methodologies. A number of areas have been the subject of some attention, but many other uses of genetic diversity have not received any attention at all. For example, even direct uses of th informational value of genetic diversity in areas such as: enzyme development by indu stries (see UNEP/CBD/SBSTTA/2/14); the agricultural use of animals; or the use in horticulture have received little or no attention at all. Other more indirect benefits, such as the role that genetic diversity plays in supporting the more strategic benefits of biodiversity in general -- climate stability or watershed functions, for exampl -- have not been considered at all. Moreover, the rapid developments of new applications for these resources makes the existing data even less complete.

49. Methodological problems also raise questions about the veracity and usefulness of much of th data that have been collected so far. As demonstrated in this Note, all of the studies carried out so far have used definitions and methodologies that have not been universally accepted, neither could they b considered as providing a reliable basis on which to implement the provision of the Convention. For example, defining the contribution that naturally occurring genetic resources make to research and development in the pharmaceutical industry has proven problematic. Indeed, differing definitions of th contribution made by naturally occurring genes has allowed researchers simultaneously to conclud that NPR is both decreasing and increasing.

50. Current understanding of this issue can therefore at best only be considered as piecemeal and anecdotal. It certainly is not possible to approximate even to a rudimentary level where, how and to what extent genetic diversity is used; let alone understand the value of that use. Such a situation does not provide a very sound basis for decision-making, and also means that there are likely to exist significant externalities and that genetic resources are not likely to be properly managed.

51. Efforts to gather more information, or empirical data, have been hampered by factors such as: (a) a suspicion about the purpose and utility of attempts to gather this information within industries that use genetic diversity; (b) confidentiality problems arising from the commercially sensitive natur of some of this information; (c) lack of resources on behalf of those undertaking the research; and (d) a lack of co-ordination and use of existing sources of information.

52. The needs of the Convention require a reliable understanding of the value of those genetic resources that are utilised and of genetic diversity in general. It is clear that there still does not exist enough information on the value of genetic resources for the needs of the Convention, neither is there a sufficiently reliable methodology for estimating the value of these resources.

53. A first step to fulfilling these needs would be to undertake a more thorough and extensive effort to collect existing empirical data on the value of genetic resources than has been possible for th

preparation of this Note. As is evident in this Note, many other processes collect relevant data and hav to some degree developed methodologies for estimating the economic value of genetic resources. To some extent, the collection of these data may be facilitated by the establishment of the clearing-house mechanism. However, there is extensive empirical data with international organisations and privat institutions that will not be accessible through this mechanism. Important international organisations and processes in this regard are the FAO; the CGIAR; CABI, the WFCC and the IDAs established under the 1977 Budapest Treaty (see inf doc for COP/3); and the international intellectual property regime under the auspices of WIPO. Because of the nature of such an ex rcise it would provide a good opportunity for developing co-operation with these processes and would also contribute to th implementation of decision II/13 of the COP.

54. The data held by private interests, the main users of genetic diversity, will not be directly accessible through the clearing-house mechanism. Moreover, these interests have, in the past, not seen the sense of developing this area. It is important that these concerns be addressed and any misconceptions dispelled so that all stakeholders are included in the process.

55. Any consideration given to the mechanism for collecting such data needs to recognise that this exercise will only provide the necessary information for the needs of the Convention if it is carried continuously and over a period of years. Short projects of limited duration will not materially address the needs of the Convention and will only add to th *ad hoc* nature of the existing information.

56. Due to the breadth of the subject matter and the limited resources availabl to tackle the needs of the Convention, an obvious strategy for making the work of the SBSTTA effective in the short ter is to focus its efforts in a limited number of areas. The SBSTTA may wish, therefore, to identify one or more areas to which special emphasis might be given. Naturally, any selection needs to be guided by the existing knowledge base, its relevance to other areas being considered by the COP and th SBSTTA, and the needs of the Parties. Such areas are not confined to the matter of access to genetic resources, but, as noted in Section 2 of this Note, also include identifying important components of biological diversity as required by Article 7, in particular the development of criteria for identifying, assessing and monitoring processes and activities that have an adverse impact on biological diversity, implementing Articles 10 and 11 with regard to incentives, and developing procedures for environmental-impact assessments. Alternatively, the SBSTTA may wish to consider emphasising a particular topic in order to support its thematic approach in general. For example, it may wish to emphasise this work in regard to marine and coastal biological diversity (see document UNEP/CBD/SBSTTA/2/15) or some other theme in preparation for future meetings, or as a result of this meeting, for example, agricultural biological diversity.

57. The lack of data and methodologies points to a need for further research both at the applied -- case study -- level and at the theoretical level. Obviously, undertaking this exercise is beyond th capacity of the SBSTTA or any other institution of the Convention. Consequently, the SBSTTA may wish to consider how it might best encourage this research in line with Article 12 of the Convention. The SBSTTA may wish to consider how it can draw on on-going academic research and conferences and present to the COP on a regular basis a review of the state of knowledge, for example, as a follo - up to the Global Biodiversity Assessment's work.

58. These factors point to the need for and benefit to the SBSTTA of considering some intercessional activity to best guide the on -going activities of the many other actors needed to b involved in developing the necessary methodologies and collecting information and data. They would then be able to contribute to meetings of the SBSTTA the type of information required for specific

topics and more generally to develop specific areas that have the greatest potential for contributing to the aims of the Convention. The SBSTTA may also wish to consider a recommendation to the COP that, given the need for considerable development of the issue, the matter be included as a standing item on the agenda of future meetings of the SBSTTA and/or the COP.

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