Does the Convention on Biodiversity Safeguard Biological Diversity?

FRANK G. MÜLLER

Department of Economics
Concordia University
1455 de Maisonneuve Blvd. W
Montreal, Quebec, Canada H3G 1MB

ABSTRACT

This paper attempts to assess and evaluate some of the economic implications of the Convention on Biological Diversity. After outlining the main principles and the scope of this Convention, the following issues are addressed: the determination of the 'optimal' level of biodiversity loss, the meaning of incremental costs, and monetary evaluation problems of ecological resources and the problems it poses for the funding mechanism (GEF). The paper concludes with a discussion of the issues of commercialisation and access to genetic resources.

KEYWORDS

Ecological economics, biological diversity, monetary evaluation, commercialisation.

I. THE PROTECTION OF BIOLOGICAL DIVERSITY AS A GLOBAL RESPONSIBILITY

Unless the global community has a death-wish, it should desire to protect the essential natural life-support systems and processes necessary to sustain its own survival. The loss of biological diversity (biodiversity) has now captured the attention of those members of the global community who are involved in the realisation of ecologically sustainable economic development and ecosystems conservation. The necessity for a comprehensive global system of managing the ecosystems and biodiversity is derived from two basic factors: the multiplicity of biological resources provides fundamentally important services for the welfare of the whole global community, and the owner-guardians of these vital resources remain generally uncompensated for the benefits provided. The

Environmental Values **9** (2000): 55–80

combination of these factors comprises the core of the problem of protection of biodiversity.

Realising this potential environmental threat, the participants of the 'Earth Summit' in Rio de Janeiro passed the 'Convention on Biological Diversity' (CBD) in December 1993, which has been signed by a majority of the world community (Grubb et al. 1993: 75).[1] The CBD provides a wider framework for the potential protection of all aspects of biodiversity, and recognises the mutual obligations between the industrialised countries (industrialised countries) and the developing countries (developing countries) in their global responsibility to maintain biodiversity and to supply additional financial funds for achieving this goal.

This paper attempts to address some of the economic problems with which the decision makers are confronted with: the determination of the 'optimal' level of biodiversity, the issue of monetary valuation of biodiversity and the problem it posed for its effective safeguarding, and finally, the potential conflict between holders of biodiversity and the biotechnology industry.

2. A GLOBAL RESPONSIBILITY: THE CONVENTION ON BIOLOGICAL DIVERSITY

The Convention's Preamble acknowledges the rapid loss of biodiversity and aims to arrest this trend for anthropocentric and ecocentric reasons, whereby the economic reasons precede (Convention 1992).[2] The explicit recognition that biodiversity has an 'intrinsic value' implies that biodiversity has to be preserved for its own sake and therefore creates an additional problem for decision makers, namely how much 'additional' biodiversity has to be saved in excess to the 'amount' of biodiversity strictly necessary for anthropocentric reasons. The Preamble also asserts that biodiversity should be protected to guarantee the continuation of evolution, the functioning of our global life-support systems of the biosphere, and to safeguard biodiversity's various values – such as ecological, genetic, social, economic, scientific, cultural, recreational, and aesthetic values – for present and future generations. For these reasons, which bestow biodiversity (and the ecosystems) the features of genuine global good, the Preamble stresses that the protection of biodiversity has to be a (or better 'the') global responsibility of the international community. Although the individual countries maintain the sovereign rights over their biological resources, the CBD, however, reminds the developing countries to use these resources in a sustainable manner – which could be interpreted as a restriction of nations' sovereignty rights in exploiting these biological resources (CBD, articles 1 and 3).

The objective of equitable and fair sharing of the benefits generated by the commercialisation of genetic resources complements the other two objectives (conservation of biodiversity and sustainable use of its components). The CBD states that the results of research and development, including the benefits generated from the commercialisation of genetic resources as well as the results and benefits derived from biotechnology, should be shared fairly and equitably and on mutually agreed terms between the industrialised countries and the developing countries (CBD, articles 15.7 and 19.2). Furthermore, the individual governments and nations maintain control over access to their resources: this right, which they have always possessed, but not always exercised, is reaffirmed by the CBD (CBD, article 15.1).

From the onset of the negotiation of the CBD the funding of preservation efforts became a crucial issue. The developing countries neither wanted nor were able to afford the expected international conservation efforts on their own, and therefore the industrialised countries were obliged to finance the developing countries' conservation programmes. As stated in other international agreements, the industrialised countries consented to bear the 'full incremental costs' of meeting the developing countries' conservation programmes[3] (articles 20 and 21). Thus, the CBD was successful in establishing a (minimal) legal commitment between the developing countries to conserve biological resources, and the obligations of industrialised countries to provide the required new and additional funds.

As expected, opposing views between the industrialised countries and developing countries emerged about the institutional structure required to administer the 'financial mechanism'. Ultimately, the industrialised countries advanced their position and requested that these funds should be integrated into the already operating 'Global Environmental Facility' (GEF), an institution which also implements other projects that contribute to the enhancement of global environmental quality. Until the Conference of Contracting Parties decides otherwise, the GEF assumes the functions of administering and allocating these funds.[4]

3. PRIORITY SETTING, FUNDING, AND VALUATION OF BIOLOGICAL DIVERSITY

3.1 Setting Conservation Priorities

If the disturbing predictions of biodiversity-loss are accurate it becomes clear that the world community cannot implement policies that will completely arrest this decline. Difficult choices have to be made to save some of the biodiversity while other parts of it are lost. The key question is, how to set priorities? Beyond an elementary defence of some charismatic or keystone species, is there a common principle or unit of account for determining the diversity of life in our global ecosystem and can this accounting principle be regarded as appropriate for the purpose of undertaking the systematic trade-off decisions required to save as much biodiversity as possible in view of limited financial budgets? At present the truthful answer is 'no', but there is always hope that some rational and practicable approach to biodiversity-preservation will be developed in the near future.

Preliminary approaches to priority setting, such as identifying species-rich 'hotspots' (Myers 1988), 'megadiversity areas' (Mittermeier and Werner 1990), and endemism were, by and large, area selections according to qualitative and quantitative species count. They may be viewed as complementary tools in an overall, yet to be developed, comprehensive preservation strategy, and they may serve useful functions in situations where immediate interventions are required, but they are unsuited for general priority setting. These approaches have numerous shortcomings, in particular the inability to discriminate and to prioritise from among priority lists themselves, and they are limited by the paucity and/or absence of adequate biological and socioeconomic information to decide cost-effectively on selecting one ecologically relevant area over another.

At this point, it is worth reiterating the more fundamental preoccupation of this paper with the protection of the environment in general (i.e., our global ecosystem) as opposed to biodiversity *per se.* Setting priorities requires full understanding of what should be prioritised: protection of ecosystem diversity or protection of biological diversity? Biodiversity and ecosystems are not synonyms, but they are very closely interrelated. Defining biodiversity is not an easy matter, and the apparent main difficulty is '... its multidimensional character, along with the fact that the dimensions are not commensurable; they cannot be reduced to a single, and therefore commensurable, statistic'(Wood 1997: 253). In the literature a consensus is emerging that the core of the biodiversity concept embraces the twin notions of biological entities/resources and the differences among these biological entities: biodiversity can be defined as the differences among biological entities.[5] This general and abstract, almost trivial, definition nevertheless allows us to clarify the distinction between biological resources and biodiversity *per se,* a distinction which is fundamental in the valuation process between biological resources and biodiversity. In the following some ecological principles have to be address which are relevant to the valuation process.

The idea that biodiversity influences ecosystem functioning is undisputed, and was apparently already recognised by Darwin who stated that ecosystem productivity depended on biodiversity (Darwin, 1872). McNaughton (1933) and other ecologists have further developed this diversity hypothesis. Odum (1953) among others suggested that the larger number of species in an ecosystem, the more numerous would be the interspecific interactions linking them and determining the ecosystem's functioning. Based on this knowledge, such ecologists hypothesised that ecosystems that contain more species should be more resistant to perturbations and disturbances, because they would contain more alternative pathways for the flow of energy and internal cycling of nutrients. Loss of biodiversity apparently interrupts this tight internal nutrient recycling, and it is assumed that as ecosystems become more open they consequently lose the nutrient endowment on which their sustained productivity had been based (Vitousek and Hooper 1993). These three hypotheses (i. biodiversity and ecosystem productivity, ii. biodiversity and ecosystem stability, and iii. biodiversity and ecosystem sustainability) are closely connected, and they seem to imply that many aspects of the stability, functioning, and sustainability of ecosystems depend on biodiversity. This dependence is not some direct and/or magical effect of biodiversity, but rather reflects the increased functional roles that can be performed in ecosystems that are species-rich. Current research results show strong dependence on biodiversity of the resistance of ecosystem functioning to disturbances, indicating that more diverse ecosystems are more stable. For example, in both simple agricultural ecosystems and in natural ecosystems, the primary productivity of ecological communities increases with a more rich biodiversity content. These findings suggest that management practices which maintain diverse forests, grasslands, etc. may help to guarantee sustained production of ecosystem goods and services. In general, we still have only limited understanding of many of these ecological processes: only few long-term experiments have been completed, while still many processes and various ecosystem types have never actually been explored experimentally. Improved knowledge is needed concerning the number of species required to warrant the sustainability of various ecosystems and how this depends on spatial patterning, spatial scale, and time. While acknowledging that there are many unsolved problems, a consensus seems to be emerging that the ability of ecosystems to supply a sustainable flow of goods and services to humans strongly relies on biodiversity, which, itself, can be sustained only if the world community alters its present course of action (Tilman 1997: 93).

Based on this knowledge, efforts have been made to derive ‘exact’ biological measures of diversity to facilitate area selections (Vane-Wright et al. 1991) and approaches using phylogenetic pattern have been developed as a suitable template for measuring species and feature diversity (Faith 1992). As mappings of independent evolutionary history between species, phylogenetic trees provide relevant information for assessing the ancestral distance between candidate species in a preservation set. When operating within limited financial budgets, the difficult decision is which species to select and which to discard. The main features of such choices are illustrated in Figures 1a and 1b, where the phylogenetic graph represents the relative number of features represented by a subset of species by the total length of the branches on the ‘tree’ occupied by the set. Figures 1a and 1b represent two different areas. Figure 1a depicts an area with

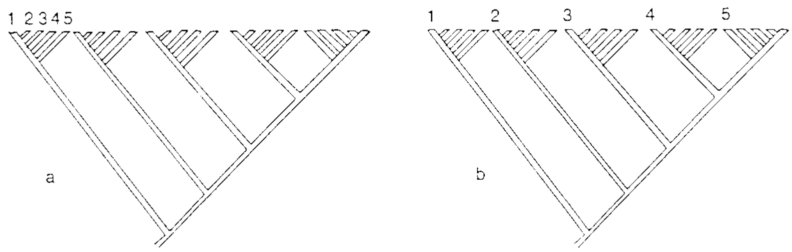

FIGURE 1. Phylogenetic pattern and area selection. The branching pattern illustrates a phylogeny with each endpoint representing a different species. The numbers 1 to 5 represent 5 species in a given area. In (a), this area has 5 closely related species, whereas in (b) the area also has 5 species, but from different families or evolutionary lineages. Although both areas have 5 species each, they differ in biodiversity (Pearce and Moran, 1997, p. 405).

five species from the same family, while Figure 1b depicts an area with one species from each of five different families. An approach based upon species richness cannot discriminate between these two areas, while a taxonomic or phylogenetic dispersion approach will reveal a preference for the broadest collection of features provided in an area, here that represented by Figure 1b. Approaches of this type seem to offer the beginning of a calculus of biodiversity, and form the basis of further developments in algorithm-based methods for selecting biodiversity-rich areas.

Considerable efforts are also being made in the development of socioeconomic approaches to priority setting (Dinerstein et al. 1993), but in view of our limited understanding of ecological processes, and confronted as we are with enormous problems of uncertainty and irreversibility, I believe the application of conventional economic methods such as cost-benefit analysis is premature, and society is better advised to follow the precautionary principle and safe minimum standards.

3.2 The Funding Mechanism: Optimal Level of Deforestation and Incremental Costs

In some industrialised countries there is a perception of biodiversity in the tropics as global biological resources and goods under open access, and the host countries, i.e., developing countries, as both the beneficiaries and the custodians of these ecosystems for the international community. The implication of this perception is that the host countries are burdened with the responsibility, besides their self-interest, to preserve the biodiversity under their jurisdiction, almost regardless of opportunity costs. The conservation of biodiversity is actually a matter of protecting entire habitats and large ecosystem regions, rather than individual species of flora and fauna. Protection of these large interrelated ecosystems with their biodiversity generates the desired beneficial global externalities (Swanson 1992: 250). Now, even if developing countries themselves and industrialised countries would jointly gain from the conservation programmes in developing countries, complex problems of income and wealth (re-)distribution, equity, and efficiency arise. Where global (beneficial or negative) ecological externalities are unidirectional, the country which is producing them tends, without international agreements, to ignore the impact of these benefits/damages on the international community. The destruction of tropical rainforests serves here as an example and is equated with the loss of biodiversity. If the 'rights' to generate these externalities belong to one country and/or a group of countries, than the international community has to respond by providing sufficiently strong incentives to the developing countries, so that they are willing to reduce and/or even to abstain from their ecologically damaging economic activities. The CBD has incorporated these aspects in its articles. Thus, the vital problem for correcting global ecological damages is how to achieve an international level of ecological-economic optimality through international cooperation, while maintaining sufficient incentives for individual countries to achieve an optimal outcome.

The industrialised countries are obliged to provide 'new and additional' funds and to meet the 'agreed full incremental costs' resulting from measures required to fulfil the Convention's objectives. The 'exact' amount of financial funds to cover the incurred 'incremental costs', however, is an outcome of bilateral negotiations between the developing countries and GEF. In addition, the CBD supplies only conditional protection of biodiversity by explicitly recognising that '...economic and social development and eradication of poverty are the first and overriding priorities of the developing countries' (CBD, article 20).

In a conventional economic framework, a full cooperative outcome and a non-cooperative outcome of the conservation problem between industrialised countries and developing countries are depicted in Figure 2. For the sake of simplicity, it is assumed that the developing countries are supplying biodiversity in the form of protected areas of tropical rainforest, and industrialised countries are interested in its provision and protection. Both parties possess full information about the domestic and global costs of deforestation and the foregone benefits of economic development (i.e., the opportunity costs). With the help of Figure 2 the factors can be identified which determine the extent of the 'incremental costs' and the magnitude of the required compensation payments. The marginal benefits of economic development (MB) and the marginal damage

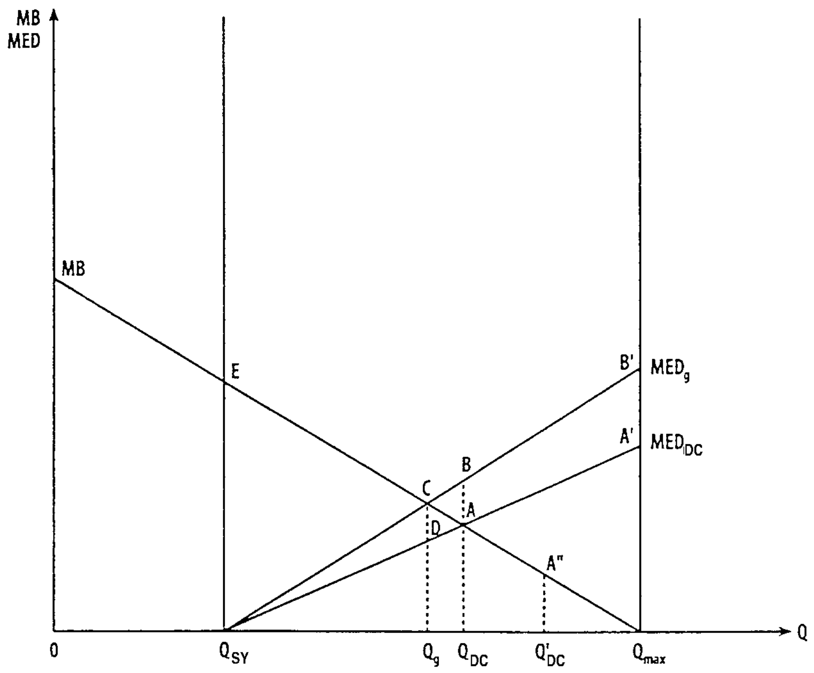

FIGURE 2. Optimal level of deforestation, incremental costs and compensation payments

costs of deforestation (MED) are recorded on the vertical axis, while the quantity of destroyed tropical rainforests (Q, measured, for example, in square kilometres per year) is shown on the horizontal axis (Müller 1996: 200).

At least two cost categories are relevant for the developing countries:

i) The opportunity costs of foregone economic development if deforestation is prevented. This type of opportunity cost includes foregone revenues of industries that could have operated in the tropical rainforests, such as cattle ranching, energy production, mineral exploration, and plantation agriculture.[6] It is plausible to assume that the marginal benefits decrease with increasing scale of deforestation, because soil productivity may decline with advanced deforestation, transportation costs tend to increase, etc.

ii) The marginal damage costs occur when human activities encroach on natural ecosystems and convert habitats in tropical rainforests for the purpose of economic development. Environmental costs may appear in form of negative impacts on climate, reduced soil productivity, industrial pollution, etc.[7]

MED_{DC} are the marginal costs for developing countries and MED_{IC} are the respective costs for the industrialised countries.[8] For example, the MED are zero at point Q_{SY}, where the rate of deforestation OQ_{SY} is identical with a sustainable yield level.

In a static context, Figure 2 shows the MB- and MED-curves and illustrates different levels of deforestation:

(i) At point Q_{max}, where MB = 0, the developing countries maximise their short-run unconstrained economic benefits, i.e., the countries are indifferent to the existing environmental damage caused by deforestation.

(ii) The intersection of MB- and MED-curves of the developing countries at point A determines the optimal level of deforestation, Q_{DC}. This national optimum, defined as Pareto-optimality, depicts a lower rate of deforestation ($Q_{DC} < Q_{max}$).

iii) The process of tropical rainforests-deforestation in developing countries produces international externalities and these inflicted costs are depicted as MED_{IC} in Figure 1 (as the difference between MED_g and MED_{DC}). The intersection of the MED_g-curve with MB-curve in point C represent the optimal global level of deforestation per time period, Q_g. The MED_g-curve is the vertical summation of national and international MED-curves.[9]

If developing countries have to be persuaded to reduce their deforestation activities to the global optimal level, then it becomes apparent that the industrialised countries have to compensate the developing countries for their incurred ‘incremental costs’. The term ‘incremental costs’ appears both in the amended Montreal Protocol and in the framework Convention on Climate Change. The CBD, however, does not provide a definition of this term. Some economists define ‘...the “extra” (or incremental) cost, [as] …the difference between the costs of *with* (or alternative case) and the *without* (or baseline case)’ (King et al. 1995: 2). According this definition, a developing country incurs incremental costs by protecting a higher level of biodiversity than is in its own national interest. In terms of Figure 2, this represents a move from point A to point C and the related ‘added financial burden’ should be allocated to the international community as a whole, so that the developing countries, implementing international conservation programmes, will not be left worse off economically. The CBD is also silent on another issue: if and when a developing country which receives compensation will also be required to pass on this compensation to the individuals who are affected by the country’s conservation intervention. This is an issue of equity, but ignoring compensation of individuals who actually incur the costs of biodiversity-protection may also pose a threat to the effectiveness and success of any such conservation policy.

If developing countries have to reduce their deforestation activities to the international optimal level, then it appears to be equitable that industrialised countries have to make compensation payments at least of the amount equal to the triangle ACD. Efficiency and equity considerations require that the beneficiaries, i.e., the industrialised countries, pay the incurring costs of maintaining the ecological capital, with all the environmental services and functions, option and existence values that the industrialised countries derive from the protected tropical rainforests. The 'beneficiary-pays-principle' provides the ethical justification and/or obligation for these international payments. At point C, the international optimal level of deforestation, the total environmental damage costs for the industrialised countries are depicted by the triangle CDQ_{SY}, i.e., their costs are reduced by the area of ABCD. At this location, the developing countries' foregone economic development benefits are diminished by an amount $AQ_{DC}Q_gC$, or in comparison to point A, a net loss of economic benefits equal to the triangle ACD. This area represents the required minimum amount of compensation to be paid by the industrialised countries to the developing countries. Or, in terms of the CBD, this amount could be considered as the 'additional incremental costs'. The industrialised countries, in contrast, have improved their welfare by an amount equal to triangle ABC. Point C can be viewed as the 'point of exploitation' of a bilateral monopoly, and it is difficult to predict what will be the outcome of the negotiated settlement.

Articles 20 and 21 of The CBD imply that the funds should only be used for clearly specified conservation projects, but there are numerous problems with GEF-project supports. Intentional environmentally damaging behaviour could become an issue in multilateral negotiation processes, since the amount of compensation payments is based upon foregone economic benefits, and/or the quality of environmental protection measures. These factors provide sufficient incentives to withhold important information and/or to supply 'manipulated' data. The GEF with its existing scientific and technical expertise could play a relevant role in this process, by reducing and/or eliminating some of the 'subjective' elements in the negotiation of project funding. The sovereignty of countries, however, limits the possibilities for the GEF's control and monitoring activities. It can be rational and in the short-term interest of developing countries for them to exploit a potentially available discretionary range of options and to deviate from a negotiated and mutually agreed programme of biodiversity-protection (Stähler 1994: 230). Some countries may offer areas with low biodiversity and/or low quality protection , i.e., they offer so-called 'lemons' in cases where complex control problems exist, because the GEF is unable to distinguish and verify the quality of developing countries' protection efforts, and thus pays financial support for assumed high-quality environmental protection. These discretionary ranges in the quality of biodiversity-protection can be regarded as a function of the difference of existing information asymmetry between developing countries and the GEF and, furthermore, of the credibility of sanctions and of punitive actions by the GEF, if a violation is confirmed. In this case, the only threat possessed by the funding agency is that of changing the contract partner. This sanction is relatively ineffective and self-defeating, since it is in the interest of the industrialised countries to protect larger biodiversity-rich areas.

Thus, a baseline is required to determine the magnitude of the incremental costs, and the question has to be answered: ‘to what are these costs incremental?’ Establishing a baseline may not be so easy, because baselines and the economics of projects are themselves affected by government policies. For example, a government plans to set up a national park. The question then arises of how this area would have been used in the absence of the government’s programme. If the area would have remained unused, or the government may have protected it anyway, regardless of the GEF’s existence, then the incremental costs would be zero and therefore, no compensation would have to be paid. In another case, an natural area might be used economically, but only as a response to perverse financial incentives established by the government’s fiscal policy.[10] If the incremental costs were determined on the basis of existing economic policies, then international transfer payments would be forthcoming and as a result (some) biodiversity might be protected: a reward for inefficient economic policy! It seems that without clearly established eligibility criteria, incentives for policy distortions arise, and the moral hazard problem may become rampant. The term of incremental costs, therefore, remains conceptually controversial and empirically unsatisfactory.

Returning to Figure 2, it has to be emphasised again that this graph shows the national and international environmental damages associated with a given rate of deforestation only in a *static* context. If developing countries continue the deforestation process at a rate faster than the rate of regrowth (or sustainable yield), so that Q_g is greater than Q_{SY}, then environmental damages will start rising even sooner in the next period. Only at point Q_{SY} where MED_{DC} and MED_{IC} are zero, is the rate of deforestation equal to regrowth, and the stock of tropical rainforests – and with it biodiversity – remains constant. In a dynamic context, even at a point such as Q_g the stock of tropical rainforests continues to shrink further, and expressing this in graphical terms, the curves move toward the point of origin and rise in the next period at a lower rate of deforestation (i.e., with a steeper slope) than before. If the rate of deforestation is not adjusted to a sustainable yield level, this dynamic process would continue indefinitely. In the process described above, even what has been defined as an international optimal rate of deforestation in economic terms, cannot prevent further decline of tropical rainforest areas and the loss of biodiversity. Available data seem to indicate that the process of deforestation hss not yet stabilised (Myers 1997: 215). The problem is that the maximum level of deforestation which is ecologically sustainable or tropical rainforest-ecosystem-safe, is not identical with the deforestation rate identified by the Pareto-efficiency criterion. Consequently, a level such as Q_{SY} has to be regarded as an ecological constraint to economic development.

Concluding, it remains doubtful whether the GEF as funding mechanism for the CBD will ultimately be successful in preserving large ecosystems and their biodiversity. Environmental projects alone are not sufficient for large-scale preservation, since such atomistic funding support policy cannot protect vital large stocks of ecological assets. In the GEF-Pilot Phase (1990 to 1994) about $1.1 billion was available for biodiversity-protection. By the end of 1993 biodiversity projects had received only a meagre $303 million. In contrast, the World Bank has more than $140 billion in lending commitments assisting economic programmes worth more than $360 billion, with annual World Bank disbursements surpassing $20 billion in 1993. Average funding of biodiversity-projects during this initial phase reached barely one percent of this amount. On this scale the GEF's influence on global biodiversity-conservation is likely to be marginal and negligible (Wells 1994: 69). Thus, the threat of substantial biodiversity losses demands that the international community has to develop substantially more comprehensive, consistent and extensive funding mechanisms which have to overcome the present limitations of the GEF. It appears, however, that the scarcest resource of our international community is not funds, but the political will to act accordingly.

3.3 The Evasiveness of Economic Valuation of Biodiversity

Since the publication of the article on 'The Value of the World's Ecosystem services and Natural Capital' in *Nature* we 'know'that the global ecosystem's value, including its biodiversity, is estimated at US$33 trillion (Costanza, et al. 1998). Was this a publicity stunt by social scientists?

Any mainstream economic approach that attempts to assign values to biodiversity is derived from an ethical framework based on utilitarian, anthropocentric and instrumental principles. The approach is utilitarian in that goods in general, and biodiversity in particular, only matter to the extent that consumers want them; it is anthropocentric in that only humans are assigning values, and finally, it is instrumentalist in that ecological goods and services are utilised as instruments to enhance human satisfaction (Randall 1988: 218). Thus, the putative values of biodiversity, such as economic, recreational values etc., are actually associated with biological goods and services, and *not* with biodiversity *per se*. This approach emphasises consumer sovereignty, which allows individuals to be their own judge of what is desirable for them. But what happens if these individual consumer preferences are unstable, capricious, or easily subjected to manipulation, or (perhaps more relevant in the case of biodiversity) what if the consumers do not even know their own preferences? Should the valuation process be based on preferences of 'experts', and if so which expert should choose them? Valuing biodiversity in economic terms is at best a challenging task.

The conventionally used dichotomy decomposes the total economic value of an ecological resource into its use value and non-use value. The use value is further subdivided into direct and indirect use value, including option value, while the non-use value may include categories such as existence value and bequest value (Pearce and Moran 1994: 19). Realising the various functions, structures, and interdependencies of ecosystems and biodiversity, this dichotomy is rather simplistic and impracticable. It seems to be more appropriate to view the large variety of services received from the ecosystem and biodiversity as a continuum of values ranging from effortlessly priced benefits (e.g., food) through values associated with less effortlessly priced goods and services to values, such as aesthetic and nature experiences, existence values, and/or moral and spiritual values, which completely defy monetary valuation (Bingham et al. 1995: 75-77). For the sake of convenience this continuum of values can be divided into three wide categories (Woods 1997: 255-256) :

i) *Some biological entities possess value as resources*. Biological resources are valuable to humans, because they are used by them for food, shelter, medicines, etc. In addition, they serve as environmental indicators for adverse environmental changes and ecosystem health, and provide environmental services such as water purification and control of water flow, prevention of soil erosion, assimilative capacity for various forms of pollution.

ii) *Some biological entities possess value as potential resources*. Some species and micro-organisms embody opportunities for the discovery of new and valuable resources, including new materials such as organic chemicals, useful knowledge, and/or genetic resources. Wild genetic resources are indispensable inputs to modern agriculture.

iii) *Some biological entities possess contributory value*. Wild plants, species, and micro-organisms may also posses contributory values, i.e., they contribute to the overall existence and functioning of ecosystems and ecosystems' integrity, which in turn generates organisms and services that are more instrumental to humans' needs. The contributory value of 'non-resource' species is indeterminate. It is fair to presume that all species have contributory value.

These three categories describe the anthropocentric, instrumental values of biological resources, but, again, they do not describe the values of biodiversity *per se*. Finally, it also has to be recognised that any economic approach that strives for 'exact' monetary value of biodiversity and/or ecosystems will eventually conflict with ethical and moral positions that question the rights of humans to become the sole judge of other species' survival.

In the centre of environmental economics are economic values of biological resources as surrogates for biodiversity and ecosystems, but it is not obvious from a scientific point of view why these economic values should have any different weight or more importance than values derived from other social or natural sciences, in the context of debate about appropriate conservation policy with the supreme objective of preventing the destruction of ecosystems and their species. Conservationist ideas have influenced the debate on biodiversity, but it appears that ultimately the text of the CBD was shaped by conventional economic rational, assessment and interests.

The obvious economic benefits of a vast availability of biodiversity for the biotechnology industry are that a 'sufficiently' vast stock of biodiversity reduces substantially the research and development costs for this industry. The naturally available biodiversity provides an extremely productive *in situ* stock of genetic resources. In general, the preservation of biodiversity also provides an insurance value, in the sense that biodiversity plays an important role in the amelioration of fundamental uncertainty and risk in ecological-economic system changes. In conventional terms, insurance is understood as a means of pooling actuarial risk. The risk relating to alterations and changes in the functioning of the interrelated ecological-economic systems may be estimated in an actuarial sense, but in most cases, these risks are evasive and inestimable. In reality, neither the set of consequences of economic interventions on the functioning of a joint ecological-economic system nor the probabilities of the occurrence of each consequence are known (Perrings 1995: 72-74). The problem is, therefore, not one of risk, but of uncertainty and, consequently, it is impossible to calculate the actuarial monetary value of biodiversity protection.

The fundamental problem for decision makers is that market prices which are used as scarcity indicators of a joint ecological-economic system are actually very imperfect indicators of the opportunity costs of committing particular components of biodiversity and ecosystem to economic uses. It is very controversial to derive values using current prices from an economic system far from ecological sustainability. By how much would the deforestation of a particular area, say 1 km^2 from an intact forest, affect the hydrological cycle or the natural pest control supplied by the forest ecosystem to an adjacent farmland? Such a marginal analysis is troublesome to conduct. It is (almost) impossible to determine the accurate economic value (i.e. marginal value) of any component of an ecosystem, let alone the aggregate of the ecosystem, including biodiversity. At present, our knowledge is insufficient about almost any gene, species and/or ecosystem function to estimate its economic value. At best, we can determine some values for biological resources, but not for biodiversity *per se.* Even in the relatively 'closed' subsystem of the market system as it is viewed by mainstream economics, economists have a poor record of accurately describing what is happening, and an worse record on even *short term* forecasting based on readily available data, such as employment, investment, money supply etc. It is difficult to comprehend how some economists could, dealing with huge, interconnected open ecological-economic systems, determine the present net or future value of any mega-ecosystem and biodiversity! It seems to be more realistic for the economic valuation process to accept the conception of biodiversity as a necessary precondition for biological resources. This is its true value, as a phenomenon transcending the conventional economic problems that are inherent in the allocation of scarce resources among competing interests. Thus, it seems that biodiversity escapes the monetary valuation process.

In addition to monetary values which economists might be able to calculate for a limited small number of species, they employ the option value concept to calculate the economic value of species of presently unknown worth. With this concept, economists attempt to determine the economic value that society should place on the possibility that future discovery and enhanced knowledge will make economically useful those species that at present are considered economically useless. One additional, yet important facet of the option value is that it could encompass all other values, i.e., use value, existence value, amenity and/or moral values. As time passes, society will gain more knowledge about all these aspects, and this advanced knowledge may lead to new use values for species, or to a new level of aesthetic appreciation, and/or society's existence and moral values may alter and some species may enjoy in the future a moral value or increased moral value that present-day society is not aware of. Thus, if assigning monetary values to these option values is a challenging task, the conceptual situation is in reality even more controversial. Actual estimation of option values in monetary terms can take place only *after* species, genes, and/or functions of ecosystems have been identified. Thus, some 'today' guesses have to be developed about the uses that these species may have, followed by assigning monetary values to those potential uses, and, furthermore, guesses are required about the probabilities of such discoveries occurring in the future (Norton 1988: 202-203). This is a daunting task !

With respect to the use value and option value of biodiversity, a plausible distinction has been made between the option value of species and the option value of biodiversity in its aggregate, in relation to ecosystems' functions and services. It seems obvious that biodiversity possesses an option value of its own at the ecosystem level, because it provides the foundation and options for future economic development – i.e., for human survival – from the functions and services of productive and inter-regional and global ecosystems. Consequently, the option value of biodiversity in relation to the ecosystem is potential huge, though actually indeterminate – unless it is a nebulous and meaningless monetary expression of human survival value (Smith 1996: 193).

In strictly economic terms, even if market failures are assumed to be fully correctable and market valuations attainable in the 'short run', questions have emerged about whether markets are able to generate efficient and intergenerational time paths, or can provide market valuations, even in theory, due to the fact of 'missing markets'. According to Bromley, '... the existence of a market still requires the wilful coming together of two consenting agents to exchange for mutual gain' (1991: 87-89). Only in the case of overlapping generations, is this 'wilful coming together' feasible. For all other situations markets are literally missing. Some economists have assumed that such a 'direct' contact between generations is not necessary to achieve efficiency because intervening markets will fulfil the same function (Solow 1974: 1-2). Bromley argues, however, that the intervening markets will only perform this function very incompletely, and thus the argument of missing markets is valid. It is, therefore, questionable whether market systems are able to achieve intergenerational efficiency and, consequently, market valuations provide doubtful bases for valuing biodiversity and ecosystems.

As an interim result, it seems fair to state that with the ratification of the CBD *no* change of paradigm in national and/or international conservation policy took place. The CBD failed to stress the ecological constraints in the concept of sustainable development; instead the monetary assessments of biodiversity – despite their evasiveness and indeterminateness – have been reemphasised. Thus, it becomes clear, as in the case of biodiversity, that a fundamental and drastic revaluation and rethinking of development and of the political order that support this process, is required. The question has to be asked: Is the objective of the CBD to secure biodiversity and ecosystem integrity, or rather to maintain the political order and the economic system that benefit in the short run from the ecological de-accumulation process? Conservationists fear the later, but want to believe the former.

4. PREFERENTIAL ACCESS TO GENETIC RESOURCES AND BIOTECHNOLOGY

Until the negotiation for the CBD began, genetic resources have been economically exploited without any payment to the countries or to the indigenous people that originally provided them.[11] The 'Common Heritage' regime and the principle of open access to genetic resources were accepted and even recognised by the U.N. system, e.g., in the FAO Undertaking on Plant Genetic Resources of 1983.[12]

If preservation of ecosystems were costless, all genetic resources would be kept. As the pressures on ecosystems have increased, owing to alternative land uses, the opportunity costs of biodiversity protection have grown as well. In general, two approaches – *in situ* and *ex situ* – are available for biodiversity protection. The *in situ* approach refers to the method that protects the genetic diversity in its ecological habitat, whereas the *ex situ* approach is a method that removes the genetic resources from its ecosystem and keeps these resources in an artificial environment such as zoos, botanical gardens, and/or germ plasm banks. The *ex situ* approach, however, is no substitute for the in situ method, since it cannot preserve complete ecosystems in their entirety (Reid et al. 1993: 7-9).

The traditional attitude concerning the control of genetic resources is now being challenged. Global population pressure, industrialised countries' lifestyle, and poverty in many developing countries are now threatening those valuable resources. If societies which possess the power to raze complete ecosystems rich in genetic resources are not compensated adequately they will have little motivation and/or incentive to protect them. In essence, the CBD establishes the principle that countries possess the sovereign property rights of their genetic resources and that these resources cannot be exploited by other countries without prior informed consent of the country of origin. Thus, it is not surprising that the access-related issues became one of the most contested one in the CBD-negotiation process. Three types of access are distinguished: i) access to genetic resources, ii) access to relevant technology, including to biotechnology and iii) access to a fair share of the benefits generated by the commercial use of the genetic materials provided by the developing countries (CBD article 15). Article 16 covers the access to and the transfer of technology, including biotechnology, whilst at the same time recognising the reservations of the industrialised countries in the areas of intellectual property rights. There is, however, no general obligation to grant preferential terms unless it is mutually agreed. The clause of 'mutual agreement' serves as a major reservation and/or check for these obligations.

Article 19 focuses exclusively on biotechnology. It includes obligations to enact measures to provide for '...effective participation in biotechnological research activities', and '... to promote ... priority access on a fair and equitable basis, especially developing countries, to the results and benefits arising from biotechnology based upon genetic resources', but these 'obligations' again are very vague and do not guarantee access for the developing countries to these benefits.[13]

Within the framework of the CBD, one emphasis has been on features of efficient contracts that could provide incentives for preservation. Preferential access to biotechnology implies that the developing countries will be at least partially exempted from paying licence and/or patent fees for biotechnological processes and/or products. Since most inventions in the biotechnology industry are the outcomes of capital intensive research efforts, the industry expects that patents and intellectual property rights should prevent imitative production by potential competitors. There exists, however, no generally accepted explanation concerning the required conditions for and the determinants of inventive processes. Conventional economics assumes that these activities will only take place under conditions of imperfect product markets. Thus, companies offering innovative commodities expect to receive rents sufficiently high to cover the sunk costs of their research and development activities. Increased competition in these markets may undermine the profitable barriers, created by patent laws, which are protecting rents and, supposedly, acting as incentives for future innovative activities. Patent rights are, however, only incomplete instruments for preventing the threat of licence-free product imitations.[14] Since the economic literature does not provide definite results as to whether protection through patent rights will cause over- or sub-optimal protection for innovative activities, it cannot be conclusively assessed how preferential access obligations under CBD will affect the future development of the biotechnology industry worldwide (Stähler 1994: 233-234).

Simple contract arrangements for the access to genetic resources are unlikely to be workable, because genetic resources cannot be purchased/sold in just one single transaction. It is quite likely that large quantities of genetic raw materials are required as prerequisite for biotechnological research to develop new products. During the initial research phase maybe limited quantities could be sufficient, but if test results give reason to believe that new pharmaceutical products can be developed, additional and larger quantities of these resources become necessary. It appears to be impracticable to gather large quantities of various species of genetic materials before any biotechnological research has proved to be promising. Sedjo views the process of collecting genetic resources '...as a lottery containing a vast number of genetic "tickets"...', each with a different potential economic payoff (Sedjo 1992: 204). This implies, that researchers experimenting with genetic resources will need continuous access to the natural habitats. The necessity for continuous access may cause another set of contractual problems between the buyers and sellers, and complicates the determination of the 'appropriate' amount of compensation, since factors such as perceptions, expectations, and strategic behaviour may also influence the contractual arrangements.[15] These factors could include risk aversion between the industrialised countries and developing countries, conflicting anticipations of future revenues, moral hazard issues (e.g., cheating on royalty payments based on asymmetrical information between buyers and sellers), and concerns about future continuing availability of genetic resources. It seems that contractual arrangements which allow modest up-front payments with royalty provisions contingent on biotechnological discoveries provide the developing countries with continuing incentives to protect their ecosystems as permanent suppliers of genetic resources (Sedjo and Simpson 1995: 84). During the present the trial-and-error period, industrialised countries and developing countries are experimenting with different contractual arrangements and divisions of activities necessary for the commercialisation of genetic resources. Even though it is unlikely that only one form of efficient contract arrangement will evolve, it is, however, paramount that these contractual arrangements must be credible, fair, and enforceable, because the absence of these features would certainly provide further disincentives to protect irreplaceable and unique ecosystems.

5. WILL COMMERCIALISATION OF GENETIC RESOURCES PROTECT BIODIVERSITY?

To recapitulate, the CBD did not lead to a paradigm shift in conservation policy of biodiversity, it rather emphasises the anthropocentric values and economic uses of biodiversity. The extraction of economic benefits from genetic resources receives high priority and the use of biotechnology is envisaged as the central instrument for that aim. The implicit 'privatisation' should help to facilitate trade in these genetic materials, and logically, the CBD promotes international free trade in genetic resources and biotechnology, and stresses the relevance of property rights, in particular intellectual property rights. The conventional economic logic of free trade promises global gains from country specialisation and exchange. If world market prices could reflect true values of ecosystem functions and biological resources, free trade could contribute to their more efficient allocation. Excessively undervalued environmental resources are a main reason of the overuse of environmental resources. When biodiversity costs are not fully internalised, and their prices do not reflect the scarcity of resources, then trade liberalisation can worsen the inefficient resource allocation, increases environmental damage, and put even more stress on ecosystem and biodiversity. This trend will be further accelerated by the process of economic globalisation, since globalisation strengthens the influence of market forces. A pronounced effect of globalisation on conservation policy is that it limits effective unilateral policy-making, and this applies to the areas of ecosystems and biodiversity protection. An individual country or enterprise which implement programmes to internalise its own or global environmental costs could become victim of its own *responsible* policy, and consequently be priced out of international markets, or lose attractiveness as a production site for foreign and/or domestic investors.

I have discussed how property rights affect economic incentives for biodiversity protection. In the following I shall analyse whether there is evidence to substantiate the opinion that the existence of an appropriate system of property rights will generate economic incentives sufficiently strong to slow down the process of biodiversity decline. Despite some very successful cases of products developed by the biotechnological and pharmaceutical industry, it would be misleading to use these gross earnings as representative values for genetic resources in general. For example, drugs derived from the Madagascan periwinkle plant have generated approximately US $100 million annually in gross revenues for the pharmaceutical company Eli Lilly (Farnsworth 1988: 94). This number is sometimes falsely quoted as the value of this particular genetic material. The gross revenues of a final product, however, cannot be used as an approximation of the potential market value for unprocessed genetic materials in the country of origin, because in most cases the biotechnological industry employs highly capital-intensive production processes and the development of a marketable drug may need years.[16] The empirical evidence of the commercial values of unprocessed genetic materials is quite scanty, and the available information suggests that the expected financial revenues from its sales alone are unlikely to become a financial panacea for the developing countries.[17] For example, for the US agricultural sector Barton estimates that the royalties for unprocessed genetic resources sought by the developing countries might amount to less than US $100 million annually (Barton 1991: 339-340). Other studies suggest that only nominal compensation for collecting genetic materials were paid, and these payments range from US$50 to US$1000 per sample received (Sedjo et al. 1995: 86). If these payments are sufficient only to recoup the collection costs, then obviously no resource rent exists. Without realised rent, the commercial values of the genetic resources would be about zero, and despite the presence of property rights system, there would be only limited economic incentives for biodiversity protection. Thus, a necessary prerequisite of property rights, and hence commercialisation, to provide economic incentives for biodiversity protection is that the ownership of these – private or public – entitlements reflects economic values. If not, property rights alone do not provide incentives for the preservation of biodiversity. There is also the issue of incomplete systems of property rights, or, if they exist, then there may be the problem of poor enforcement. Under either situation, there exists in effect an open access regime with all its known consequences for resource management and protection of biodiversity.

This situation could become aggravated if ‘poaching’ occurs and genetic resources become contraband to be sold on international black markets. It is quite possible to imagine a situation where adjacent countries share a mega-ecosystem, but one of these countries is either selling the genetic resources inexpensively and/or is not protecting the specific information of these genetic resources, and as a consequence this country is preventing adjacent countries from capturing any economic gains by developing their genetic resource-based industry.[18]

As an interim conclusion, it can be summarised that biodiversity prospecting could generate (some) revenues for the biodiversity-rich developing countries, including their local communities, but the amounts involved are quite likely marginal in comparison to the market value of the final commercial product. Given the magnitude of revenues generated by the biotechnological industry worldwide, even a relatively small percentage of these revenues could mean still substantial revenues for developing countries. Thus, if developing countries are developing and improving their own biotechnological capacities, biodiversity-prospecting and the biotechnological industry have the potential to become an important sector in their economy. The revenues, generated through international trade of genetic materials will nevertheless remain woefully inadequate to finance the protection of biodiversity on a large scale in developing countries.

Beside the financial aspects of commercialisation of genetic resources is the technological aspect of this process and its impact on biodiversity. It is a prevalent misconception to assume that biotechnological development will naturally support biodiversity conservation. The core of this problem is related to the fact that biotechnologies are essentially technologies for producing *uniformity* in genetic materials. The diversity of industrial strategies and the diversity of species and plants within the global life-support system are not identical, and market competition can hardly be viewed as a substitute for ecosystem evolution in the creation of biodiversity. Industrial strategies and production can bring forth diversification of commodities, but they cannot enhance nature's biodiversity.[19] The seed industry uses heterogenous genetic material from many different natural habitats as inputs to develop 'new' commercial seeds, but the commodity 'seed' that is sold to the agricultural community is characterised by uniformity (Kloppenburg 1988: 117-120). In pursuit of economic efficiency, it appears that biodiversity is incompatible with economic efficiency and productivity, which demand uniformity and monocultures to exploit economies of scale. This leads, however, to the paradoxical situation in which biotechnological manipulations of genetic materials contribute to the decline of biodiversity. The irony of this is that it reduces the very resource stock on which biotechnology industry depends upon.[20] Thus, biotechnological innovations in all areas, such as agriculture, forestry, and animal husbandry, are production processes which lead to more widespread uniformity and become a major threat to the protection of biodiversity and sustainability. It appears that the '*Biodiversity-Biotechnology-Biobusiness-Biodiversity Protection*'' link is very feeble in economic terms for generating sufficient funds for biodiversity protection, and very tenuous in scientific terms. Hence, by emphasising biotechnology and commercialisation of biodiversity the CBD may have contributed to accelerating the process of reductionism and fragmentation of ecosystems into their marketable parts so that they can be treated as mere inputs. Such commercial reductionism might be convenient for strictly economic concerns but it will threaten the global life-support system. Thus, how much and how well biotechnology and biodiversity prospecting will contribute to ecological sustainable economic development for a particular country, will ultimately depend upon the developing countries governments' and institutions' will to introduce and implement the necessary policies.

6. EPILOGUE

Safeguarding biodiversity is an objective of paramount global importance, but does the CBD provide hope for the developing countries, including their indigenous people, and for the conservation of biodiversity itself, or is this convention, despite all the efforts of the international community, just another international agreement without any real consequences? Given the political parameters and the size and the complexity of the task, the CBD represents a respectable political achievement, and contains provisions that have the potential to be transformed into concrete measures toward an ecologically sustainable economic development pattern. In the core of the CBD are the principles that governments agreed on the urgency for a more global and comprehensive approach to protect and to use genetic resources; the need for additional and new financial assistance to developing countries; and on the exchange, on a fair and equitable basis, of genetic resources for access to and transfer of biotechnology. Thus, the CBD as a key element in the overall long run and global goal of sustainable development, forces the international community to address and to re-visit the 'distributive question'. The re-addressing of these issues appears to many mainstream economists and decision makers as a return to mediaeval thinking about 'pretium iustum'. The ongoing debate on sustainable development is not focusing on the distribution problem *per se*, but rather on thorny distributive issues such as a fair and equitable income and wealth distribution between industrialised countries and developing countries, between present and future generations, and the scale of global economic system with respect to the global ecosystem. Without progress on these issues, the realisation of sustainable development will remain a chimera.

In essence, the CBD stresses clearly an anthropocentric and utilitarian approach for the protection of biodiversity, and supports the process of turning genetic resources into marketable commodities. This position creates antagonistic tensions between the objectives of preservation of biodiversity and commercialisation of biodiversity. But by just backtracking for a moment, one realises that environmental deterioration, destruction of habitats, monocultural agriculture, depletion of fish stocks, etc., are all intricately linked to the present economic system, its technology and its cultural values. Thus, by offering the assets of biodiversity as resources to (mainly) commercial interests, we are in the process of entrusting 'the agents of environmental destruction' with safeguarding our global ecosystem and biodiversity, and ultimately our own long run survival.[21]

NOTES

[1] Initially the government of the United States of America refused to sign the CBD owing to the pressure exercised by its biotechnology industry. Recently the Clinton Administration joined the convention, but upheld several provisions for the protection of this industry's interests.
[2] The paper focuses on the articles which have direct economic consequences. For a detailed legal interpretation see e.g., de Klemm (1993).
[3] See, e.g., the Montreal Protocol on Substances that Deplete the Ozone Layer.
[4] For a careful assessment of the CBD in political science terms, see Suplie (1995).
[5] A very thoughtful discussion on this subject is provided by Wood (1997). For the sake of simplification the terms biological resources, environmental resources and genetic resources are used as synonyms in this article.
[6] In reality, some of these foregone economic benefits are not to the full extent an economic loss for the developing countries. Since many of these companies are foreign owned, a large proportion of these benefits is expatriated (Swaney and Olson, 1992).
[7] Recent threats to ecosystem health are e.g., the uncontrolled polluting activities of oil exploration by companies from developing countries and industrialised countries, like the US Occidental Petroleum Corporation in the Río Tigre region in the Peruvian Amazon (Der Spiegel 1996: 180).
[8] The MED-curve for the industrialised countries is not separately drawn.
[9] For the sake of simplicity a separate curve, representing only international marginal damages, is omitted in this figure.
[10] See, e.g., Binswanger's study of Brazil's perverse incentives, which were identified as the main source for the accelerated deforestation process in that country (Binswanger 1987).
[11] Kloppenburg provides numerous examples of new plants supplied by the New World (Kloppenburg 1988:154).
[12] The International Undertaking on Plant Genetic Resources (FAO 1983) is a non-binding agreement among governments.
[13] A detailed interpretation of the articles of the CBD is provided by Shine and Kohona, 1992.
[14] On patent rights and biotechnology see Swanson (1994: 231).
[15] For a fine survey on various contractual arrangements for sharing biodiversity benefits see Rosenthal (1997: 253).
[16] DiMasi estimates that it takes on average about US $230 million and 12 years to develop a marketable product (DiMasi et al. 1991: 107).
[17] For a detailed discussion of empirical studies see Reid et al. 1993, chs. 1 and 2.
[18] It is also imaginable that unscrupulous companies intentionally select the least-protected or least-organised country (and/or in collusion with corrupt officials) for their operations with the purpose to mine this developing country's genetic resource stock and to sell these resources internationally before the developing country is in the position to correct the situation.
[19] Agricultural crops require constant infusion of fresh germplasm. Thanks to this 'topping up' of the main crops, the US Department of Agriculture estimates that germplasm contributions lead to increase in productivity that average around 1 percent annually, with farm-gate value over US$1 billion (Myers 1997: 257).

[20] It has to be pointed out that biotechnology and biodiversity with its genetic information are complements, not substitutes, in the production process.
[21] Or, a closer look at the verbal twins 'biodiversity' and 'biotechnology' may reveal that biotechnology may well be a fox in the chicken coop of biodiversity. Foxes love chickens. Foxes have certain types of expert knowledge about chicken. Foxes genuinely believe in the importance of monitoring and accessing chicken coops, and may have even clever policies for the promotion of their public acceptance. But careful: all this does not predestine foxes to be good guardians for chickens. (von Weiszäcker 1996: 65).

REFERENCES

Barton, J. 1991. 'Relating Scientific and Commercial Worlds in Genetic Resources Negotiation'. Paper presented at Symposium on Property Rights, Biotechnology, and Genetic Resources; Nairobi, Kenya.
Bingham, G. et al. 1995. 'Issues in Ecosystem Valuation. Improving Information for Decision Making'. *Ecological Economics*, **14**(2): 73-90.
Binswanger, H. 1987. *Fiscal and Legal Incentives with Environmental Effects on the Brazilian Amazon*. Washington, DC: World Bank
Bromley, D. 1991. *Environment and Economy: Property Rights and Public Policy*. Oxford: Blackwell.
Convention on Biological Diversity, 1992. UN Doc. UNEP/Bio. Div/N7-INC. 54. Text in: *International Legal Materials*, **31**: 822-41.
Costanza, R. 1998. 'The Value of the World's Ecosystem Services and Natural Capital'. *Ecological Economics*, **25**: 3-15.
Der Spiegel 1996. 'Schillernde Brühe'. No. 14, 180-181.
Darwin, C. 1872. *The Origin of Species*, 6th London edition, facs. Chicago: Thompson and Thomas, 1982.
DiMasi, J., R. Hansen, H. Grabowski, and L. Lasagna 1991. 'Cost of Innovation in the Pharmaceutical Industry'. Journal of Health Economics, **10**: 107-142.
Dinerstein, E. and E. Wikramanake 1993. 'Beyond Hotspots: How to prioritize Investments to conserve Biodiversity in the Indo-Pacific Region'. *Conservation Biology*, **7**: 53–65.
Faith, D. 1992. 'Conservation Evaluation and Phylogenetic Diversity'. *Biological Conservation* **61**: 1–10.
FAO 1983. *International Undertaking on Plant Genetic Resources*. Rome.
Farnsworth, N. 1988. 'Screening Plants for New Medicines'. In Wilson, E. (ed.), *Biodiversity*. Washington: National Academy Press.
Grubb, M., M. Koch, A. Munson, F. Sullivan, and K. Thomson 1993. *The 'Earth Summit' Agreements: A guide and Assessment*. London: Earthscan Publications.
King, K., and M. Munasinghe (editors) 1995. *Ozone Layer Protection: Country Incremental Costs*. Washington, DC: World Bank.
Klemm de, C., and C. Shine 1993. 'Biological Diversity Conservation and Law. Legal Mechanisms for Conserving Species and Ecosystems'. IUCN Environmental Policy and Law Paper, no. 29. Gland: IUCN.
Kloppenburg, J. 1988. *First the Seed. The Political Economy of Plant Biotechnology, 1492–2000*. Cambridge: Cambridge University Press.

McNaughton, S. 1993. ‘Biodiversity and Function of Grazing Ecosystems’. In E. Schulze, and H. Mooney (eds), *Biodiversity and Ecosystem Functions*, pp.361–383. Berlin: Springer Verlag.

Mittermeier, R., and T. Werner 1990. ‘Wealth of Plants and Animals Unites “Megadiversity” Countries’. *Tropicus*, **4**: 4–5.

Montreal Protocol on Substances that Deplete the Ozone Layer. Montreal, September 17, 1987. In *International Legal Materials*, **26**: 1550–61.

Müller, F. 1996. ‘Transfer Payments to Developing Countries for Environmental Protection: A Viewpoint’. *International Journal of Environmental Studies*, **49**: 197–207.

Myers, N. 1988. ‘Threatened Biotas: “Hot spots” in Tropical Forests’. *The Environmentalist* **8**: 187–208.

Myers, N. 1997. ‘The World’s Forests and Their Ecosystem Services’. In G.Daily (ed.), *Nature’s Services*, pp. 215-33. W ashington, DC: Island Press.

Norton, B. 1988. ‘Commodity, Amenity, and Morality: The Limits of Quantification in Valuing Biodiversity’. In: E. Wilson (ed.), *Biodiversity*, pp. 200-205. Washington, DC: National Academy Press.

Odum, E. 1953. *Fundamentals of Ecology*. Philadelphia: Saunders.

Pearce, D. and D. Moran 1994. *The Economic Value of Biodiversity*. London: Earthcan Publications.

Pearce, D. and D. Moran 1997. ‘The Economics of Biological Diversity Conservation’. In P. Fiedler and P. Kareiva (eds), *Conservation Biology*, 2nd edition, pp. 384-409. New York: International Thomson Publishing.

Perrings, C. 1995. ‘Biodiversity Conservation as Insurance’. In Swanson, T. (ed.), *The Economics and Ecology of Biodiversity Decline: The Forces Driving Global Change,* pp. 69-77. Cambridge: Cambridge University Press.

Randall, A. 1988. ‘What Mainstream Economists Have to Say About the Value of Biodiversity’. In E. Wilson (ed.), *Biodiversity*, pp. 217–23. Washington DC: National Academy Press.

Reid, W., S. Laird et al. 1993. *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development*. Washington DC: World Resources Institute.

Rosenthal, J. 1997. ‘Equitable Sharing of Biodiversity Benefits: Agreements on Genetic Resources’. In *Investing in Biological Diversity*, pp. 253-74. OECD Proceedings, Paris.

Sedjo, R. 1992. ‘Property Rights, Genetic Resources, and Biotechnological Change’. *Journal of Law and Economics*, **35**: 199–213.

Sedjo, R. and R. Simpson 1995. ‘Property Rights, Externalities, and Biodiversity’. In: T. Swanson (ed.), *The Economics and Ecology of Biodiversity Decline: The Forces Driving Global Change,* pp. 79-90. Cambridge: Cambridge University Press.

Shine, C., and P. Kohona 1992. ‘The Convention on Biological Diversity: Bridging the Gap Between Conservation and Development’. *Review of European Community and International Environmental Law*, **1**(3): 278–288.

Smith, F. 1996. ‘Biological Diversity, Ecosystem Stability, and Economic Development’. *Ecological Economics*, **11**: 191–203.

Stähler, F. 1994. ‘Biological Diversity: The International Management of Genetic Resources and its Impact on Biotechnology’. *Ecological Economics*, **11**: 227–236.

Solow, R. 1974. ‘The Economics of Resources or the Resources of Economics’. *American Economic Review*, **64**: 1–14.

Suplie, J. 1995. 'Streit auf Noahs Arche: Zur Genese der Biodiversitäts-Konvention'. Working Papers, FS 2–95–406, Science Center Berlin.

Swaney, J., and P. Ohlson 1992. 'The Economics of Biodiversity: Lives and Lifestyles'. *Journal of Economic Issues*, **26**(1): 1–25.

Swanson, T. 1992. 'Economics of a Biodiversity Convention'. *Ambio*, **21**(3): 250–257.

Swanson, T. 1994. *International Regulations of Extinction*. London: Macmillan Press.

Tilman, D. 1997. 'Biodiversity and Ecosystem Functioning'. In: G. Daily (ed.), *Nature's Services.* pp. 93–112. Washington, DC: Island Press.

Vane-Wright, R., C. Humphries and P. Williams 1991. 'What to Protect – Systematics and the Agony of Choice'. *Biological Conservation*, **55**: 235–254.

Vitousek, P., and D. Hooper 1993. 'Biological Diversity and Terrestrial Ecosystem Biochemistry'. In E. Schulze and H. Mooney (eds), *Biodiversity and Ecosystem Function*, pp. 3-14. Berlin: Springer Verlag.

von Weiszäcker, C. 1996. 'Biodiversity Newspeak'. In: M. Baumann, J. Bell et al. (eds), *The Life Industry: Biodiversity, People and Profits,* pp. 53-68. London: Intermediate Technology Publications.

Wells, M. 1994. 'The Global Environmental Facility and Prospects for Biodiversity Conservation'. *International Environmental Affairs*, **6**(1): 69–97.

Wood, P. 1997. 'Biodiversity as the Source of Biological Resources'. *Environmental Values*, **6**(3): 251–268.