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Biodiversity: luxury or necessity?

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1. Introduction

Biodiversity—a contraction of biological diversity—appears at first sight to be a simple concept, i.e. the total sum of biotic variation, ranging from the genetic level to ecosystems. On closer examination, however, the concept is more complex; it is used to indicate the diversity of species, the diversity within species, and the diversity of ecosystems. Two important aspects are the quality and the quantity of biodiversity. The quantity can be expressed in terms of the size of the population, the abundance of different species, as well as the surface area and number of ecosystems in an area. Quality (or integrity) relates to the genetic diversity and the vitality or resilience of a species, ecosystem or natural area.

A central problem is a continuing loss of biodiversity around the globe, but our knowledge about biodiversity is still relatively limited (Loreau et al., 2001; Martens and Rotmans, 2002). The first problem with biodiversity is that our model of nature is constructed hierarchically, i.e. from the molecular level up to the ecosystem level. Within this construction, we distinguish logical classes, such as individuals, populations, species, communities and ecosystems, with the presumption that each member of a certain class can be distinguished from every other member. However, in reality 'boundaries' between, for example, sub-species and between ecosystems are often unclear, and it is practically not possible to exhaustively list all the species and their location, let alone to name all the populations or individuals at a lower hierarchical level. Furthermore, the interactions between biotic and abiotic processes, and the mutual dependencies between individuals, populations, species and ecosystems are difficult to map. Nevertheless, this is what biodiversity is all about. We wish to explore a phenomenon that we can never fully examine or map fully. We will, therefore, have to accept that—as a result of our lack of knowledge—the study of biodiversity will always be surrounded by structural uncertainty.

A second problem is that for many ecosystems it is difficult to determine which loss of genes/populations/species/ecosystems the current system can handle and, therefore, continue to exist, or which loss causes the system to develop into a different system or to disappear. Sometimes, ecosystems can continue to function, at least partially, even though a majority of the common species have become extinct. On the other hand, it has been known since Darwin's time (1859) that a large variety of species has a positive influence on the productivity and stability of ecosystems (Loreau et al., 2001).

The question that is then raised brings us to the third problem, namely: which populations, species and ecosystems are essential in view of the coherence and vitality of the natural environment (and which not)? The preservation of the abundance of species is not the same as the conservation of the total biodiversity. To many people, biodiversity is a universal good that must be retained, just like Mozart's concerts, paintings by Van Gogh or books by Hemingway. But how many words can be deleted, for example, before the meaning of an article or book is lost? Continuing this metaphor, is saving one population of every species the same as saving one of every note from a Mozart concert (Chapin et al., 2000)?

Finally, the spatial division of biodiversity across the globe is extremely heterogeneous, which makes generalisations difficult. Some areas, such as coral reefs and tropical rain forests, have a great deal of biological variation and other areas, such as Arctic regions or deserts, have hardly any. An unambiguous explanation of this spatial heterogeneity has yet to been given, but recent research has shown that the quantity of available energy, the structure of the area (including soil composition), the climate conditions (temperature, rainfall and humidity) and local versus regional diversity are important explanatory factors. Spatial patterns in biodiversity never have a single cause; there is always more than one (Gaston, 2000).

As the global system grows more interconnected, the fate of the world's biodiversity will increasingly depend on global changes. Despite the complexity of the issue,

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there is a need to explore how future developments will affect global levels of biodiversity. In this paper we will place biodiversity scenarios in the enveloping context of global scenarios.

2. Causes and driving forces of biodiversity loss

Current estimates about the extinction of species are mainly based on the relation between the number of species and the size of the area available for them. Such estimates lead to an estimate of the total loss of species of approximately 27,000 per year (including ‘lower’ species groups, like insects), or one species every 20 min (Wilson, 1992). Even though there is a great deal of criticism about this type of estimate and despite its fundamental uncertainties, there is agreement about the fact that there is a significant, rapid decline in the number of species, which in some cases may be called alarming (Purvis and Hector, 2000). The trend is unmistakable that the human domination of ecosystems leads to a clear decline in biodiversity within many habitats and accelerates the process of extinction throughout the world. Although the extinction of species is a natural process, the current speed of extinction of species through human intervention is approximately 100–1000 times faster than the natural speed of extinction. In many groups of organisms 5–20% of all species are already extinct (Chapin et al., 2000).

This accelerated loss of species is, however, not the only factor in the general loss of biodiversity. Factors such as the division of species and genetic diversity are just as important, as is the question of what the effect is of the estimated loss of species on the functioning of ecosystems. In view of the dependence of our society on the biosphere, the decline in biodiversity is clearly a cause of great concern.

There are two main processes that result in loss of biodiversity:

- a reduction in the size of natural areas, and
- a change in ecosystem conditions.

On a global scale, the most important causes of the loss of natural areas are their conversion to agriculture and cattle breeding and, to a smaller extent, urbanisation. The most important causes of a change in ecosystem conditions are pollution, disruption, fragmentation and isolation of natural areas, climate changes, eutrophication, pollution, erosion and the introduction of new species. It is important to note that the supposed causal mechanism should be considered at different hierarchical levels. Where the cause of disruption of biodiversity can be a predation at the individual level and a syndrome for populations, it may well be a climate change for ecosystems (Mooney et al., 1995).

If we analyse the most important driving forces behind these causes for the loss of biodiversity, we face a number of generic forces that, to a large extent, determine both the loss of natural acreage and the changing conditions for the species. First of all, the longing for an increase in prosperity not only increases consumption, but also leads to large-scale changes in consumption and production patterns. Increases in prosperity and economic growth generally lead to spatial development that places natural areas under constantly increasing pressure. Changes to infrastructure and urbanisation contribute, on the one hand, to improving the living standards (through increased mobility and housing developments), but on the other hand, take place at the expense of the quality of nature and the environment. Since the space used per capita is still increasing substantially, the availability of free space is being placed under considerable pressure.

Furthermore, developed countries place increasing pressure on natural resources by intensifying trade, communication, consumption and production and, in doing so, place considerable pressure on the biodiversity of developing countries. The relationship between developing countries and developed countries is becoming clearer and more direct. The demand for natural goods and services from consumers in developed countries is directly related to producers in the North and South via international markets. And since the trend in most developing countries is towards export-oriented development (mainly stimulated by foreign aid), developing countries are becoming increasingly sensitive to changes in the quantity and quality of the goods and services desired.

The driving force in developing countries themselves is fulfilment of the basic necessities of life, such as shelter, food, health and security. This generates an increase in the demand for food, energy, water and fuel (wood) in order to be able to survive. To support this constantly increasing demand for the primary necessities of life and the increasing pressure from developed countries, more and more demands are made on the available natural resources. This leads to a destruction of the habitat (deforestation), changes to the habitat, in terms of soil, water and air pollution, toxification and the extraction of groundwater, as well as the break-up of the habitat due to urbanisation.

On the other hand, an increase in poverty can lead to major migrations, which in turn cause new areas to become cultivated. However, migration can also mean that abandoned areas become available to nature.

A positive side effect of increasing prosperity is technological development. This normally improves efficiency so that, for instance, more food can be produced on less agricultural land. This is, however, also coupled with increasing intensification, the use of more pesticides, and an increase in the use of water, which in turn increases the environmental pressure placed on natural resources. On the other hand, technological development means that new techniques become available for extracting raw materials from areas to which there was previously no access and which can add practical value to natural materials that have not been used in the past. Similar consequences of technological development result in extra pressure being placed on biodiversity.

Tourism and recreation are also important driving forces behind the loss of biodiversity in terms of disruption and pollution of natural areas. On the other hand, tourism can also ensure that more effort is made to preserve nature areas through the use of protective measures. Finally, education and information also to a large extent determine the support base for the protection of nature areas. A lack of knowledge about how to deal with natural resources efficiently and the importance of these resources for society have led to large-scale destruction of natural and semi-natural ecosystems.

It may be obvious that both historical and current loss of biodiversity is closely related to rapid growth in the global population, which has quadrupled over the last 100 years, as well as to the increased volume of human consumption, which is reflected in a fivefold increase in the gross national product per head of the world population—a rough measure of consumption (Maddison, 1995). The worldwide use of land, water, minerals and other natural resources through human activities has increased more than tenfold in the last two centuries (Rotmans and de Vries, 1997). Dominant activities related to this pressure on natural resources are agriculture, cattle breeding, fishing, industrial production, transport, tourism, recreation and domestic activities.

3. Biodiversity—why worry?

The role of biodiversity in determining the health of ecosystems involves the relationship between biodiversity and their stability and productivity. In recent years, the relationship between species diversity and the stability and productivity of ecosystems has been researched in various ways: via experimental field research, the formulation of mechanistic theories, and quantitative field observation. The provisional findings of this research show that greater species diversity is in general linked to an increase in the productivity and stability of ecosystems, as well as increased uptake of nutrients. Field experiments in Europe and the United States have shown that halving the number of plant species in certain areas leads to a reduction in productivity of approximately 10–20% (Tilman et al., 1996). Greater biodiversity generally leads to the more efficient use of the available natural resources, because there is more chance that species will be present that are able to cope with specific circumstances in a habitat. Anticipating new biotic and abiotic preconditions and the coexistence between species based on differentiation and heterogeneity are the most important mechanisms behind the natural evolution of biodiversity. The species currently on Earth are the result of a natural selection process over the last three billion years, which has led to a large degree of specialisation.

Species diversity is therefore a prerequisite for ecosystems to function. But how important are species and ecosystems for society? This can be researched by investigating the functions and associated goods and services of ecosystems that are important for humans. These are supplied by species that ensure the conversion of materials and energy into products, and they produce food, water, fuel and medicine. Furthermore, they ensure the reuse of waste, drive the global biogeochemical cycles and regulate the world climate. Biodiversity on Earth is the source of many pharmaceutical medicines, as well as all plants, of which the most important three (corn, rice and wheat) provide 60% of the human food supply. The vitality of these species, and therefore the food supply, is directly related to the variety of species (Fehr, 1984). In the future food supply will partly depend on the development of new crops originating from what are now wild plants, because diseases and resistance against pesticides will increasingly affect current crops and, ultimately, make them unsuitable for food production.

Loss of biodiversity can have important consequences for the well-being and prosperity of human populations in both developing and developed countries, because it reduces the strength and capacity of ecosystems to provide essential goods and services. These include cultural, historical, scientific and educational resources. Reductions in the availability of food and water and in the natural resources needed to make medicines have the potential to damage our health.

Damage to species and natural ecosystems, as well as a change in the composition of species, can also have far-reaching consequences from an economic point of view. For example, the introduction of deep-rooted species (such as Eucalyptus) in a dry area may reduce the availability of water and considerably increase the price of water for human use. Examples are known where the extra cost of the supply of water and/or agriculture increased by up to a hundred million dollars per year (Chapin et al., 2000). The value climate regulation services of a tropical rain forest is estimated to be approximately 250 dollars per hectare per year (Costanza et al., 1997). The economic damage (in particular to agriculture) caused by the introduction of new, exotic species is very well documented, but difficult to quantify. In the United States, estimates of the cost of invasions of exotic species vary from approximately 1 billion dollars to 150 billion dollars per year (Pimentel et al., 2000). In Australia, this annual cost is estimated to be approximately 2 billion dollars per year (Thorp, 1997).

Global environmental change, such as climate change, can potentially influence the decline in biodiversity. The complex interrelationships between the irreversible loss of species and ecosystem processes may lead to powerful non-linear social consequences in the future. This is particularly the case if threshold values relating to the resilience of ecosystems are exceeded, resulting in rapidly increasing social costs. Social adaptation is difficult and costly in this type of situation. It is important to gain a better understanding of the non-linear dynamics of social costs resulting from the loss of biodiversity.

So it appears that the driving forces behind the advancing loss of biodiversity are complex, with both an economic, socio-cultural and an ecological component. We can roughly state that, in the early stages of socio-economic transition, in which many developing countries now find themselves, social dynamics are the major driving force behind the decline in biodiversity. The primary need for food, energy, water and fuel deeply and often irreversibly reduces the ecological capital. This leads to a decrease in the quality and quantity of natural ecosystems, as well as a significant loss of species. Just fulfilling the primary needs of those living in such areas places enormous pressure on available land.

In a later stage of the socio-economic transition, the pressure comes mainly from economic sources. There is then a relative shift from the pressure placed on biodiversity by socio-cultural dynamics to that exerted by economic dynamics. The shift from agricultural to industrial activities, exacerbated by related developments in infrastructure and transport, ensures that extra pressure is placed on biodiversity. The increase in material prosperity plays a decisive role here. In time, this has major consequences for the ecological capital. On the one hand, natural resources are overexploited, for instance, through over fishing, erosion of fertile land and soil contamination, often with disastrous consequences for biodiversity. On the other hand, the indirect effects of disruption to the bio-ecological cycle and climate change can, in the long term, very seriously and irreversibly affect biodiversity. Climate change can lead to extra drought in areas where there is already a water shortage and where the biodiversity is already under considerable pressure. Such an accelerated decline in biodiversity can threaten the livelihoods of many of the inhabitants of developing countries.

In conclusion it can be said that the problem of biodiversity decline is not just an environmental problem; it is also a socio-economic problem, perhaps even more so than other environmental problems. If we wish to bring about change, then a change is required in our production and consumption patterns, which has radical consequences for the socio-economic infrastructure. In combination with feedback from persistent environmental problems related to biodiversity, this ensures that biodiversity will remain on the agenda for some time to come.

4. Looking ahead

So what lies ahead? In order to explore possible future global biodiversity patterns we have made use of a set of scenarios. Scenarios do not predict the future, but rather paint pictures of possible futures and explore the various outcomes that might result if certain basic assumptions are changed. The scenarios used explore the global and regional dynamics that may result from changes at a political, economic, demographic, technological and social level, and are based on the recent efforts of the IPCC (IPCC, 2000). The distinction between classes of scenarios was broadly structured by defining them ex ante along two dimensions. The first dimension relates to the extent both of economic convergence and of social and cultural interactions across regions; the second has to do with the balance between economic objectives and environmental and equity objectives. This process therefore led to the creation of four scenario 'families' or 'clusters', each containing a number of specific scenarios.

4.1. The A1 scenario group

The A1 scenario offers an unfavourable perspective for the pressure on biodiversity. When we consider the main driving forces of biodiversity change, we see that the population continues to rise to more than eight billion people in 2050, after which it slowly declines to seven billion. Economic growth is the strongest of all scenarios, which will lead to a significant increase in the consumption of natural resources and energy. Technological improvements, in combination with the high levels of income, result in a considerable improvement in communication and transportation facilities. Car ownership, for example, will fall sharply. Current differences between rich and poor countries are expected largely to disappear. These developments will put significant pressure on both the quantity and quality of biodiversity. Although the A1 scenario projects almost no changes in total land use, it is very likely that many pristine natural areas with a large degree of biodiversity will be converted into man-made areas. Probably, new natural areas will be created but these will have significant less biodiversity, as they require time to restore.

A potential problem will be the expected increase in land prices, which will result in difficulties for NGOs or governments that wish to buy and preserve remaining natural areas. Selling natural areas will be more profitable than preserving them (even when many of the ecosystem services are taken into account). Nature restoration projects will also be significantly hampered by pressures such as islandisation (fragmentation and isolation of natural areas) by transportation infrastructures, intensive agriculture, and large urbanised areas. These pressures also reduce the ecosystem quality of other areas as a result of increased population densities, sprawling suburbanisation, dense transportation networks, and increased tourism (with higher incomes).

An important side-effect of this scenario is higher concentrations of greenhouse gases in the atmosphere due to a substantial increase in energy use and land conversion. A global mean increase in temperature of at least 2.5°C will significantly affect the quality of natural areas, which will be more sensitive for these changes as they already have to cope with numerous other pressures. Although the distinction between countries will decrease, many will face major natural disasters such as floods, storms and wildfires (partly initiated by climate change) that can significantly impact society and biodiversity. A recent example is the forest fires in Indonesia.

Biodiversity under this scenario faces significant losses, continuing the current trend. Almost all pressures currently identified will increase. It is assumed that ecological systems are resilient, but the question is: how many natural areas will remain and with what quality.

4.2. The A2 scenario group

The second group of scenarios envisages a heterogeneous world. This future world image is very diverse and different for each region. This makes it very difficult to estimate the impact on global biodiversity. An important characteristic of the A2 scenario, which would significantly affect global biodiversity, is a continually growing human population that is expected to reach a total of almost 15 billion in 2100. This will significantly increase demand for cultivated land (agricultural and municipal areas) and related transportation infrastructures. Although economic growth is limited, the total consumption of natural resources will be considerable. The main focus will be on regional and local culture in an extremely heterogeneous world where environmental concerns are relatively weak. Initiatives to preserve global natural resources are more difficult to implement regionally. In addition, the economic transition will take place much more slowly than under the A1 scenario, resulting in slower improvements in production methods and thus greater pressures on the quality of biodiversity (e.g. through pollution).

The prospects this presents for biodiversity are not very encouraging: sharply increasing demand for food, water, energy and land will result in a significant loss of natural ecosystems and species. Therefore, the quantity of biodiversity will be substantially reduced. Just as in the A1 scenario, all pressures on biodiversity will continue to increase, leading to a rapid decrease in the quality of biodiversity. In several regions there will be a lack of good-quality natural resources. As a result, competition for these resources within and between countries will increase, which will negatively affect the economic conditions in these countries. It will also strongly impact ecosystems, as conflicts tend to reduce attention for the preservation of natural resources, but also often lead to large numbers of refugees fleeing to nearby areas/countries. Furthermore, the total number of those in the earliest stage of transition will be much larger. Often with low levels of education and less access to health infrastructure, these people will live mainly in developing countries, many of which make a significant contribution to global biodiversity. Their populations often rely much more on local ecosystem functions (production and regulation), which makes the preservation of the remaining natural areas more difficult and uncertain. An increasing number of people will compete for a declining number of natural resources at the cost of the quantity and quality of those remaining resources. Investments will mainly be made to strengthen local social and cultural infrastructure, and less to preserve nature. The resulting loss of natural ecosystems can have dramatic consequences for local communities, especially in developing countries where many societies are dependent on the quality of their natural resources. Conflicts over the use of the scarce water, fertile land and wood will inevitably arise.

4.3. The B1 scenario group

This third group of scenarios offers a more favourable perspective for biodiversity. A sharp reduction in arable farming and cattle breeding acreage is expected, coupled to a strong increase in productivity. The reduction in the production of a number of plants is not as strong as in the A1 scenario cluster, for example. After a slight reduction in tropical rain forests worldwide, there is an increase in the second half of this century. Natural ecosystems are less affected, both in quantity and quality. The estimated temperature increase is not particularly high, resulting in less pressure on biodiversity than in the other scenarios, and the pressure from population growth is considerably lower. Furthermore, a lot is done to improve ecological capital. The speed with which such a transition to a balanced development takes place determines the reduction of threatening factors and prospects for biodiversity.

4.4. The B2 scenario group

In the fourth group of scenarios, a world unfolds in which the approach to social, economic and ecological problems is primarily a local one. In such a future world, the pressure on natural system is greatly reduced, due to high average educational levels and the high degree of organisation within communities. As a result, energy and material-efficient techniques can be developed. The regional differences are also very large, so that a global trend in biodiversity is difficult to estimate. It can be said that through the strong emphasis on local and regional social and technological regulations, protection of nature and the environment receives a high priority. As a result, the availability of natural acreage could increase and the loss of species could be brought to a standstill.

These scenarios show that it is expected that changes in land use and factors related to this (consumption and production behaviour creating demand for energy, food, water and natural resources, which affect the use of land) remain the most important driving forces behind the loss of biodiversity. The result of this is that current driving forces behind the loss of biodiversity will remain, both in terms of quality and quantity: changes in land use, destruction of natural areas, smaller populations, nitrogen deposition, the introduction of species, and climate change. An important element of uncertainty when estimating future change in biodiversity is the degree of interaction between the most important causes of changes in biodiversity. Interactions, for example, between a change in land use, climate change and the introduction of species, can be synergetic (reinforcing each other) or antagonistic (weakening each other) (Sala et al., 2000).

The general picture of the future as far as the loss of biodiversity is concerned largely depends on the introduction of socio-economic policies that support local and regional initiatives to achieve structural solutions. The main issue is how to provide a good standard of living for growing populations without impoverishing the planet.

5. Conclusions

Because biodiversity is so complex and varied, knowledge in this area is still relatively limited. This has important consequences for setting up and implementing robust policy. It can be stated that this complexity, combined with structural uncertainty, may well lead to an unpredictable future and further loss of biodiversity which will be characterised by non-linearity, thresholds and irreversibility. This situation demands a policy approach that is both better though out and more integrated than those adopted up to now.

An efficient policy which is much more orientated towards coherence could contain the following points: (i) The setting up of a research program which is a combination of experimental and mechanical research in order to adequately explain the complex relations between variety and species and the dynamics of natural ecosystems, so that insight can be gained into essential ecosystems, species and populations. The various services and functions of natural ecosystems must be mapped out in much greater detail, including the uncertainties. This will provide the basis for a more accurate estimation of the expected socioeconomic and ecological effects from the loss of biodiversity. (ii) Making the general public, policy makers and land managers aware of the consequences of the present fast and irreversible decline in biodiversity. Despite convincing scientific evidence, the general public is largely unaware of the large-scale socioeconomic and ecological effects such a decline in biodiversity may cause. Also, people are insufficiently aware that adjustment strategies are usually inefficient once these effects are discovered. (iii) Managers should consider the ecological and social consequences of the loss of biodiversity in every phase of the planning process for the use of land. Better planning, management and response measures can provide better management of the landscape with the preservation, or even reinforcement, of regional biodiversity. Integral considerations must be made where estimates of future costs as a result of an advancing harmful effect on ecosystem services are considered against the avoided costs (benefits) as a result of a specific biodiversity policy. (iv) Create a functional (or effective) ecological infrastructure based on the latest knowledge and insights in biodiversity conservation theory and management (e.g. on minimum critical ecosystem size, dispersal mechanisms, etc.). And finally: (v) Create a stronger interrelation between socioeconomic policy and biodiversity policy.

Such a policy must be able to rapidly incorporate new knowledge about ecosystem services and changes in global environmental circumstances, as well as fast-changing social needs. The policy must, of course, also take into account partial structural uncertainties about biodiversity. On the other hand, enough is known about a number of species, communities and ecosystems to make it possible to formulate effective policy now.

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