Managing biodiversity correctly – Efficient portfolio management as an effective way of protecting species

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Loss of biodiversity is regarded as one of the key problems affecting the environment.

In order to demonstrate the significance of biodiversity, the value of individual species or ecosystems today is generally determined in science and practice. The underlying thought is that a species or ecosystem is worthy of being conserved provided its value exceeds the benefit of its loss. This is, at first glance, a rational line of thought typical of economists.

As this study shows, however, this way of looking at the situation is inadequate. Biodiversity, rather like a share portfolio or a portfolio of insurance risks, is concerned with a portfolio of different genes, species or ecosystems.

The finding from portfolio theory that in portfolios returns are additive whereas risks diversify and that well managed portfolios frequently also contain securities which, viewed in isolation, appear to hold little attraction, is now generally acknowledged in the management of securities.

Portfolio theory is not currently brought into discussions on biodiversity issues, and that is regrettable. The way in which biodiversity is generally viewed at present lags more than fifty years behind securities management. This study shows how portfolio managers would look at and manage biodiversity. Probably the most surprising and provocative finding is that it may be assumed that portfolio managers would conserve more species than appears appropriate from the way the situation is usually viewed at present.

Frank Figge

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Preface

Few theoretical concepts have such great significance for the practical work of financial service providers as portfolio theory. It explains how financial service providers transform individual risks into collective security for their clients. Security is an important basis for sustainable economic development and one of the core competencies of the Gerling Group.

As portfolio theory shows, diversity occupies a key position in this context. While future returns cannot be predicted with certainty, financial service providers combine risks which are independent of each other in portfolios. The result is portfolios that are more attractive than the individual risks. The diversity of a financial investment is therefore increased and the overall risk of the portfolio is reduced. A reduction in diversity may sometimes promise higher returns: portfolio management shows that a higher portfolio risk is the price to be paid for this type of greater return. The conservation of Creation, that is to say for Gerling respect for man and nature, has long been part of our corporate culture. As insurers, we are aware of the significance of an intact environment for sustainable development. We are therefore particularly pleased to be able to present, with this study, a publication which associates the instruments of our activity in an innovative way with the values to which we feel committed.

As practitioners of portfolio management, we know that the full value of diversity can only be recognised if a portfolio view is adopted. In our opinion, this also applies to biodiversity. Although looking at individual species, as is commonly done at present, is interesting and important, it cannot demonstrate the value of biodiversity.

The conservation of biodiversity cannot be undertaken as an accumulation of the protection of species and ecosystems. It is necessary instead to adopt a holistic approach, as expressed in the concept of sustainable development. Long-term considerations and future expectations represent the basis on which decisions are taken both by portfolio managers and by biodiversity managers. A problem facing the biodiversity manager is that there may not yet be any “value” or benefit specifically visible to him when he comes to make decisions. The potential should nevertheless not be underestimated. A large part of modern pharmacy is already based on components discovered in the animals and plants of the rainforests. The need for efficient management of the natural diversity of species is therefore already evident today.

The long-term “principles of conserving value”, that is to say diversity in itself, represent a task which also permits changes in the composition of species. This may at first seem disconcerting, as it has the consequence that individual species (values) may be removed from a portfolio or not even included in it, while others are included whose value at first appears dubious, in order to minimise the portfolio risk. Ethical and moral issues could be raised here, but these arise more from the classical contrast between the nature conservation and environmental conservation movements and in our view are not really tenable in practice.

Gerling has set itself a clear benchmark in the context of its corporate mission: the purpose of our business is “in dialogue with our clients to come up with the best possible safeguarding services (...) and to shape an exceptional and responsible business (...), in harmony with Creation, to the benefit of Man and Nature.” Solving global problems such as climate change, social justice and protection of the diversity of species is therefore also very important to our corporation and will have a major bearing on the life and economic activities of society in the 21st Century.

We are convinced that the study presented here fills an important methodological gap. It ensures that portfolio theory, which has persistently made a mark on asset management over the last fifty years, is now also available for the management of the greatest asset of all: the management of biological diversity.

Stefan Volk
Chief Financial Officer
Gerling Versicherungs-Beteiligungs AG

Cologne, November 2001

"The preservation of biological diversity is also a vital task for future generations. It is the basis for sustainable development and economic growth." UNEP/ETU, 1998

Introduction

Loss of diversity is regarded today as one of the great unsolved problems facing the environment (e.g. Swanson 1991, p. 181). Biodiversity describes both the quantity and diversity of genes, species and ecosystems (e.g. Gaston & Spicer 1998; Groombridge et al. 1992, p. xiii; Lévêque 1997, p. 7; Pearce 1995). Biodiversity is lost, for example, through species becoming extinct or a decline in genetic diversity. The decline in biodiversity as an ecological problem has attracted increased public interest in recent years. Mankind has, however, long been concerned with issues relating to the conservation of biodiversity.

An old …

This can be seen, for example, in the Bible (e.g. Birnbacher 1986). In the Old Testament, God addresses Noah with the following words and gives instructions on how life on Earth is to be conserved in the face of the Flood:

"Of every clean beast thou shalt take to thee by sevens, the male and his female; and of beasts that are not clean by two, the male and his female, to keep seed alive upon the face of all the earth."(Genesis 7, 2-3)

Similar accounts can be found in other religious texts, for instance in the Koran (cf. for example Sure 11, 40).

… and also economic topic

These instructions are generally interpreted as an ethical or religious request to conserve biodiversity. They can also, however, be interpreted economically, and this is not acknowledged. The instructions are a response to a typical economic challenge. In the description given in the Bible, the Ark which is to save Noah and his family from the Flood, with its dimensions of 300 times 50 times 30 cubits (Genesis 6, 15) and its three storeys (Genesis 6, 16), has limited capacity. It represents a typical economic phenomenon: scarcity. God's instructions therefore reflect a decision taking account of scarcity or, to be succinct, a typical economic decision.

Optimising instead of maximising

The contents of the instructions are, however, unusual for another reason. The commandment to Noah refrains from saving as many "clean" animals as possible in view of scarcity. It puts the diversity of animal species ahead of the benefit of the individual animals and in so doing pithily expresses the knowledge of an experienced portfolio manager.

Markowitz, who is commonly referred to as the father of modern portfolio theory, also points out through a reference to Shakespeare that deliberate diversification is not a new phenomenon (Markowitz 1999, p. 5):

My ventures are not in one bottom trusted,
Nor to one place; nor is my whole estate
Upon the fortune of this present year:
Therefore my merchandise makes me not sad.
(Shakespeare, Merchant of Venice)

It is therefore all the more surprising in connection with the decline in biodiversity that the discussion in recent years has mainly been about the correct valuation of species and biodiversity (e.g. Dixon & Sherman 1991; Fromm 2000; Garrod & Willis 1999; Gauthier 1998; Gowdy 1997; Lerch 1999; Pearce & Barbier 2000; Weikard 1998). Whether a value can and should be put on biodiversity is at the same time controversially discussed (e.g. Hampicke 1999; Pirscher 1997).

Lack of consideration of diversity

Many authors attach only secondary importance in this context to issues of diversity, despite the concept of biodiversity, i.e. the diversity of species, genes or ecosystems, in valuation and management issues. This is regrettable, as it must be anticipated that the value of biodiversity is determined not just by the quantity but by the degree of diversity. If no account is taken of the degree of diversity, there is a risk of incorrect decisions being taken.

Portfolio theory as a theory of diversity

The emergence of portfolio theory (Markowitz 1952; Markowitz 1959) provided issues of the diversity of portfolios with a theoretical framework. Markowitz's thoughts generally related to securities. They have not just had a theoretical benefit there but have also had a great impact on the behaviour of asset managers such as banks and insurance companies in the practical situation.

Interestingly, the parallels between issues of diversification of securities and issues of natural diversity are generally not acknowledged. This is surprising, because the correlation between diversity and stability in ecology has long been discussed (cf. for example Cronk 1997; Fjeldså & Lovett 1997; Goodman 1975; Hobohm 2000). Those authors who recognise the risk-reducing effect and therefore the economic value of diversification sometimes even term this the portfolio effect and refer to the parallels with the economic sciences (e.g. Groombridge et al. 1992, p. 426; Perrings 1995, p. 862; Swanson 1992; Swanson & Goeschl 1998). They recognise that the risk can be reduced by combining various species in a portfolio (Myers 1980; Swanson 1992) and in some cases even that the variation in return from the elements in relation to each other is of particular significance (Groombridge et al. 1992, pp. 426-430).

The authors do not, however, explicitly refer to portfolio *theory* for an explanation.[1)] This is regrettable for two reasons. Firstly, only portfolio theory explains the precise connection between return and risks of individual species and the return-risk ratio of portfolios. A higher number of species, genes or ecosystems does not always lead to a lower risk. Only portfolio theory shows if additional elements in a portfolio also reduce the risk. Secondly, the findings of portfolio theory provide the basis for modern portfolio management, which is of fundamental significance to the professional management of securities today. If it is assumed that a decline in biodiversity is unavoidable, the ratio between return and risk must be managed efficiently. The conclusion that diversity has to be maximised (Swanson 1992) offers little assistance in this context.

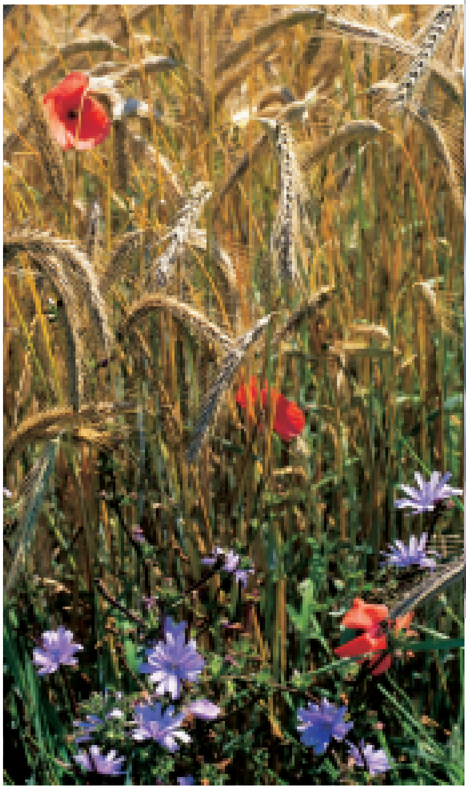
Disregarding portfolio theory has a notable consequence. Concepts corresponding to the state of scientific knowledge in the fifties of the last century are used in looking at biodiversity. This results in stock portfolios today being managed more professionally than the largest portfolio of all: our environment.

Antiquated concepts

The fact that portfolio theory has not been applied to date in connection with biodiversity is perhaps also due to the fact that it is often felt to be difficult to understand. This study therefore puts great emphasis on understandability. Consequently it does not contain any exposition of the mathematical basis of portfolio theory. This can be gleaned from reading the relevant (introductory) literature (e.g. Brealey & Myers 1996, pp. 173-195; Garz et al. 2000, pp. 17-97; Markowitz 1952; Markowitz 1959). Once the thoughts underlying portfolio theory are understood, it is not difficult to transfer them to biodiversity.

[1] It is also shown that the authors do not refer to portfolio theory by the fact that they do not consider some fundamental questions of portfolio theory. These include, for example, the question of the optimum weighing of portfolio elements.

"A wide range of natural resources is used in industry to provide food, medicines, fabrics and an assortment of other products. Ensuring that these resources are continuously available is therefore essential for business." WBCSD/IUCN, 1997



Biodiversity: A societal asset

Environment as a …

Mankind or – expressed in slightly more abstract terms – all economic subjects depend on the natural environment. Human economic activity would be impossible without the natural environment. The natural environment therefore fulfils all the conditions to be regarded from the point of view of economic science as an "asset" (e.g. Pearce & Barbier 2000). An asset is a *stock* whose value is deduced from a *future flow of benefit* (e.g. Schmidt & Terberger 1997, p. 48; Krüsselberg 1984, p. 5). In so far as the natural environment, for example in the form of agricultural yields, as a supplier of natural remedies, but also for example as a tourist destination supplies a benefit in the future, it qualifies as an asset (e.g. Smith 1996b).[2]

… significant asset

It is obviously difficult to make a comprehensive estimation of the value of biodiversity. This is due to biodiversity at the same time having a fundamental and complex character. The annual market value alone of the products derived from genetic resources is estimated at between 500 and 800 billion US dollars (Ten Kate & Laird 2000). A study of the whole ecosystem of the world estimates the annual benefit at between 16 and 64 trillion US dollars (Costanza et al. 1997). Biodiversity is without doubt a significant asset.

There are a number of other assets alongside the natural environment. These include securities such as shares. The value of shares is also derived from their future benefit. In the case of shares, this future benefit consists of the expected cash flows to the investors. Investors profit from dividends, rises in share prices and – more rarely – the proceeds from liquidation.

Separation of valuation and asset management

The economic sciences have long been concerned with the valuation and management of such assets created by humans. In the context of securities, they differentiate two issues. Firstly the value of the asset is ascertained by valuation, for example company or share valuation (for an introduction to the various valuation techniques, cf. e.g. Damodaran 1996). Secondly, portfolio management is concerned with the question of the optimum composition of a portfolio of these assets (cf. for an introduction e.g. Garz et al. 2000; Grinold & Kahn 2000). This separation between valuation of assets and composition of portfolios is also reflected in the practice of asset management. Banks generally separate the functions of analysts from the functions of portfolio managers. The principal task of analysts is to estimate the value of securities. Portfolio managers, on the other hand, decide which securities are considered in what quantity in the portfolios. Investors assume that value can be created not just from a "correct" valuation but from suitable composition of the portfolio as well. To summarise briefly, its is portfolio managers who decide on investments, not analysts.

[2] For an overview of other flows of benefit from biodiversity, cf. for example Geisendorf et al. 1998; Myers 1980. In describing the benefit of the environment, this study generally refers to agricultural and pharmaceutical benefit. The reason for this is that this benefit is immediately understandable and is probably also undisputed. These observations are, however, in principle applicable to any flow of benefit which accrues in the future and cannot be predicted with certainty.

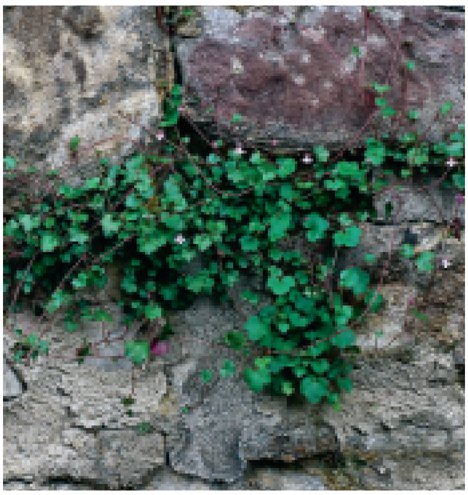
One-sided orientation in valuation

It is noticeable that economic questions of biodiversity to date are only looked at from an analyst‘s perspective. The issue of the value of species (e.g. Artuso 1999; Boman & Bostedt 1995; Simpson et al. 1996; Stevens et al. 1997) or of ecosystems (e.g. Barbier 1994; Dixon & Sherman 1991; Laughland et al. 1996) is to the fore. The decline in biodiversity is then, logically, attributed to biodiversity being incorrectly valued (Wood 1997) or to the value and costs of conserving the species or ecosystem falling apart (Drucker et al. 2001; Geisendorf et al. 1998, p. 170; Mason 1996; Perrings 1995, p. 829; Swanson 1996; Swanson 1999, p. 307). It is implicitly, or even explicitly, assumed that conservation is economically appropriate if the expected benefit exceeds the expected costs (e.g. Dixon & Sherman 1991; Pearce 1995).

The way in which portfolio managers view the situation, on the other hand, is largely ignored. This is surprising, because it is specifically the task of a portfolio manager to diversify portfolios in an optimum manner. The task of a portfolio manager of biodiversity, by analogy, would be to ensure the optimum degree of natural diversity. Analysts cannot perform this task, nor is it their task.

The study examines both the point of view of analysts and that of portfolio managers. The topic of the following section is the valuation of individual species or parts of biodiversity and therefore adopts an analyst‘s perspective. It answers the question of what the value of a species or ecosystem depends on.

The subsequent section transfers the basic principles of portfolio theory to issues of biodiversity and in so doing lays the foundations for a portfolio theory of biodiversity. The next section considers the consequences which may result from a portfolio approach of this kind for the management of biodiversity. Some rules are presented which, in the management of stock portfolios, are already regarded as self-evident today and can be deduced from the key rule of portfolio theory: return is additive and risks partly cancel each other out.



The analyst's perspective: valuation of species and ecosystems

There are various methods for valuing species and ecosystems. It would go beyond the scope of this study to give a full account of all the methods. In addition, there are a number of excellent accounts of the various methods of valuation (e.g. Geisendorf et al. 1998; Heywood et al. 1995; Kopp & Smith 1993; Nunes & van den Bergh 2001; Organization for Economic Cooperation and Development 1992; Pearce & Turner 1990; Perrings 1995; Smith 1996a).

The aspects flowing into the value established are more important than the precise procedure followed in the methods of valuation used. Only a broad classification of the various methods of valuation is therefore made in the following. There then follows a discussion of the aspects on which the value of diversity depends, irrespective of the method of valuation chosen.

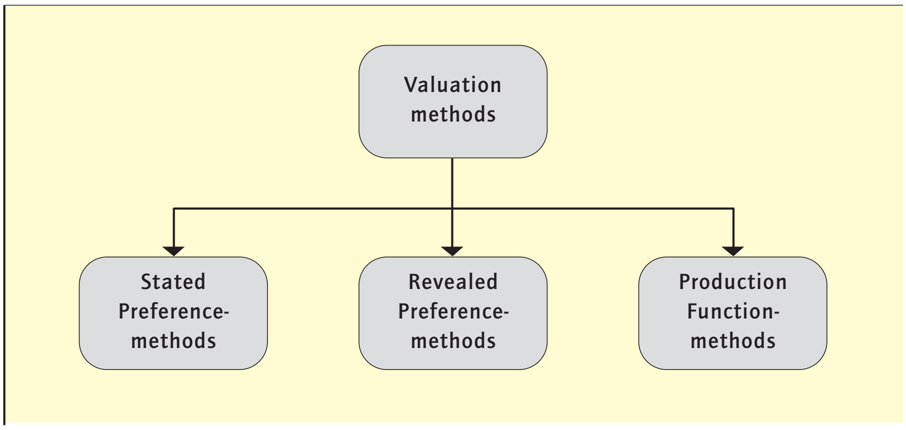
Methods of valuation

A broad distinction can be made between three major methods for valuing biodiversity (Figure 1):

- *Stated Preference Methods* simulate market situations (e.g. Heywood et al. 1995; Pearce & Barbier 2000). They refer to surveys, which construct market-like situations and determine the preferences of respondents.

- *Revealed Preference Methods* observe the actual behaviour of people in markets and in this way draw inferences on the value (e.g. Heywood et al. 1995; Pearce & Barbier 2000). It is possible to determine what costs people incur in order to make use of an ecosystem. These costs allow a statement to be made on the value which they attribute to the ecosystem.

Figure 1: Economic valuation methods



- Economic processes require directly ecological resources or at least presuppose that they exist. Ecological resources therefore represent an input for economic processes. *Production Function Methods* determine value by ascertaining the effect of a change in input on economic output (e.g. Heywood et al. 1995; Narain & Fisher 1995).

Anthropocentric utilitarian approach

The methods mentioned adopt an anthropocentric utilitarian point of view; the value of biodiversity is therefore derived from its benefit to man. The common features nevertheless extend beyond the common perspective. Regardless of the method of valuation chosen, three aspects have an effect on the value of a species or of biodiversity.

No value without benefit

If a value is to arise, *firstly* a benefit must be expected. If no benefit accrues, no value arises either. This benefit may consist in an agricultural yield but also, for example in the aesthetic benefit of a landscape. The value depends among other things on the level of the benefit. This benefit accrues in the future. A past benefit does not have any effect on present value. Two other aspects result from this.

Today instead of tomorrow

The value depends *secondly* on the time preference of the users of the resource. It is generally assumed that people prefer consumption of a resource today over later consumption (Bernholz & Breyer 1993). The later the benefit of a resource accrues, therefore, the lower its present value is. As the benefit does not accrue until the future, it is furthermore uncertain.

Greater value through less risk

Value depends *thirdly* on people‘s attraction or aversion to risk. It is generally assumed in the economic sciences that people do not like taking risks. They are averse to risk and are therefore prepared to sacrifice part of the return for a decline in risk.

If the environment is treated as an asset, the value of species, genes or ecosystems depends on *what return* is to be expected *when* and *at what risk.*

Diversification of risks – additivity of return: fundamental features of a portfolio theory of biodiversity

1. Stock portfolio

Return is additive – risks cancel each other out

Return and risk are also at the centre of portfolio theory. Portfolio theory and portfolio management make use of a phenomenon which is observed in the formation of stock portfolios: returns are additive, while risks partially cancel each other out (Markowitz 1952; Markowitz 1959).

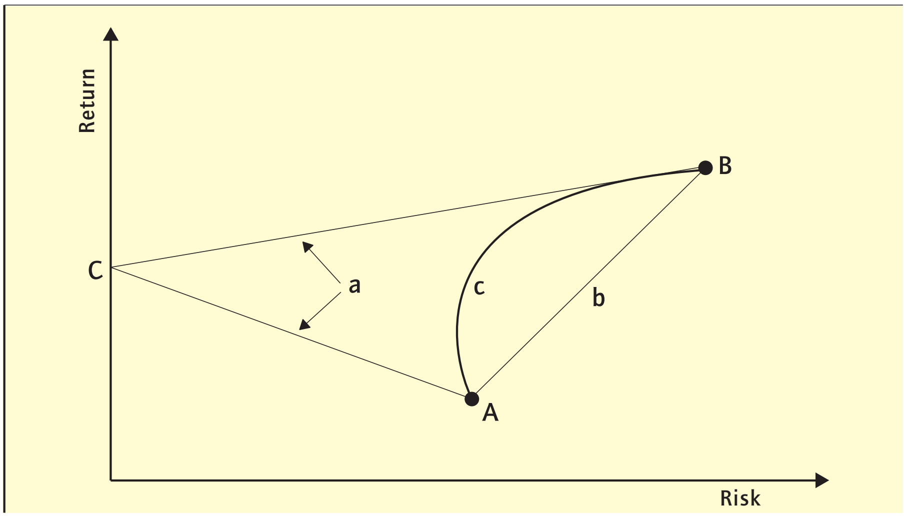
This phenomenon allows portfolio managers to lower the risk of the complete portfolio without necessarily sacrificing return. As investors are generally regarded as averse to risk (e.g. Bodie et al. 1999, p. 148), from the point of view of the investor this leads to an improvement in portfolios, that is to say to a higher value.

These relationships are first explained below by taking the example of a portfolio containing two securities (e.g. shares) (similarly e.g. Bodie et al. 1999; Elton & Gruber 1987). These observations are then transferred to biodiversity portfolios.

Three items of information are required in order to be able to describe the stock portfolio (e.g. Olson 1999, p. 83):

- What expected return and what expected risk does stock A have?
- What expected return and what expected risk does stock B have?
- What relationship exists between the variation in return of the two stocks?

Figure 2: Relationship between return and risk for a stock portfolio (similarly e.g. Elton & Gruber 1987, p. 44)



Variations in return

The question of the variation in return is of particular interest here. Three typical variations in return can be distinguished. The stocks may firstly vary in a *parallel* manner. Whenever stock A gains in value, stock B gains in value too. Stocks may, secondly, vary in an *opposed* manner. If stock A loses in value, stock B gains in value. The variation may also be *uncorrelated,* i.e. not show any relationship.

Diversification effect

The relationship between the variation in return on the two stocks is important, because it determines the risk of the complete portfolio. Stocks whose variation in return is uncorrelated or even opposed are of particular interest to portfolio managers. Stocks with an opposed variation in return are, however, rare. In such cases the risks of the individual stocks cancel each other out as a result of the loss on one stock being offset by the gain on another stock (line a in Figure 2). The point where the portfolio is on line a depends on the weighting of the particular stock in the portfolio. The risk can even be completely diversified away by correctly weighting the stock (point C). In this case the loss on one stock is always offset by a corresponding gain on the other stock.

This diversification effect does not come to bear, however, if the stocks follow a completely parallel variation in return. The portfolio in this case, depending on the particular weighting, is on line b. If stock A performs well, this is also true of stock B.

What are biodiversity portfolios?

Portfolio theory generally relates to stock portfolios. In practice, however, there is not just one but a large number of possible stock portfolios. Portfolios can be differentiated for example with regard to type of stock (e.g. shares or bonds) or geographically (e.g. Europe or North America). In practice, portfolios are characterised by the stocks which the portfolio is to contain being defined; portfolios with differing return-risk characteristics arise. What portfolio is managed by a portfolio manager depends on the needs and preferences of the investor. Share and bond portfolios are, for example, often managed separately from each other and portfolios are distinguished according to regions in which they invest.

A similar situation also arises for biodiversity portfolios. Here too, possible portfolios differ according to the needs and preferences of those who have an interest in the portfolios. A farmer, for example, has an interest in a biodiversity portfolio which encompasses all crop-plant and animal species which he can make use of for production or which affect the return on his portfolio. As the portfolio manager of his biodiversity portfolio, he puts the portfolio together in such a way that the benefit and risk of the portfolio meet his preferences. A pharmaceutical company in the same country, for its part, has an interest in all species which might have a pharmaceutical use in the future. This portfolio will differ from the farmer's portfolio.

Society profits not just from the agricultural and pharmaceutical use, but also for example from the use of biodiversity for tourism. In addition, it is not just the biodiversity of a region of a country that is significant but at least the biodiversity of the whole country. From the macroeconomic point of view, a national biodiversity portfolio of this kind may contain all the species which in the future, directly or indirectly, might have a social use.

In practice, the return on stocks is more or less correlated, and generally neither a completely parallel (line b) nor a completely opposed (line a) variation in return exists. Line c therefore best describes the variation in return to be found in practice.

This relationship applies analogously to portfolios containing more than two stocks.

2. Biodiversity portfolios

These observations can be transferred in an analogous manner to issues of biodiversity. The various species, genes or ecosystems have an expected return and therefore also a value. The return, in the anthropocentric utilitarian point of view adopted here, consists of the expected benefit which society derives from the species, genes or ecosystems. This includes, for example, the supply of food or use for tourism. This return is, however, uncertain, that it is to say attended by risk. This risk can be partially diversified by combining various species, genes or ecosystems in a portfolio (Groombridge et al. 1992, pp. 426-430; Heywood et al. 1995, p. 862; Swanson 1992; Swanson 1994). There is no single biodiversity portfolio, but rather a series of different portfolios. The following box provides examples of different biodiversity portfolios.

Crop plants as an example

A portfolio of crop plants can be taken as an example of the effect of diversification. The future yield of crop plants such as maize or soya is uncertain (e.g. Kaylen et al. 1992; Porter et al. 1998). These crop plants can be combined in a portfolio. Depending on the relationship between the yields of the species contained in the portfolio, the characteristics of the portfolio differ more or less clearly from the characteristics of the individual crop plants. It is appropriate to assume that the variation in the yield of crop plant species as a rule is positively correlated (e.g. Groombridge et al. 1992, pp. 430-433; Lamadji et al. 1995). Good weather conditions, for example, will lead to high yields for crop plants. Adverse weather conditions, such as drought, lead to losses (Kaylen et al. 1992, p. 517; Naylor et al. 1997, p. 52). It is unlikely, however, that yields are perfectly correlated. Different organisms have differing ecological tolerances in relation to variable environmental factors (ecological valency) (e.g. Schäller 1991). While one crop plant, for example, can withstand drought, another proves its merit in wet weather conditions.

An American study comparing the relationship between the variability of wheat yields with the size of the cultivated area shows that an agricultural portfolio effect of this type is more than a theoretical construct. All other things being equal, with a larger cultivated area the portfolio size should increase and the portfolio variability fall. This portfolio effect can in fact also be observed (Schurle 1996).

Analogous transfer to other types of benefit is possible

Similar portfolio observations can also made for example for future, tourist, aesthetic or pharmaceutical benefit. Here too the future benefit in general is uncertain and does not correlate or does not correlate completely.

Figure 3: Return-risk relationship of a crop-plant portfolio

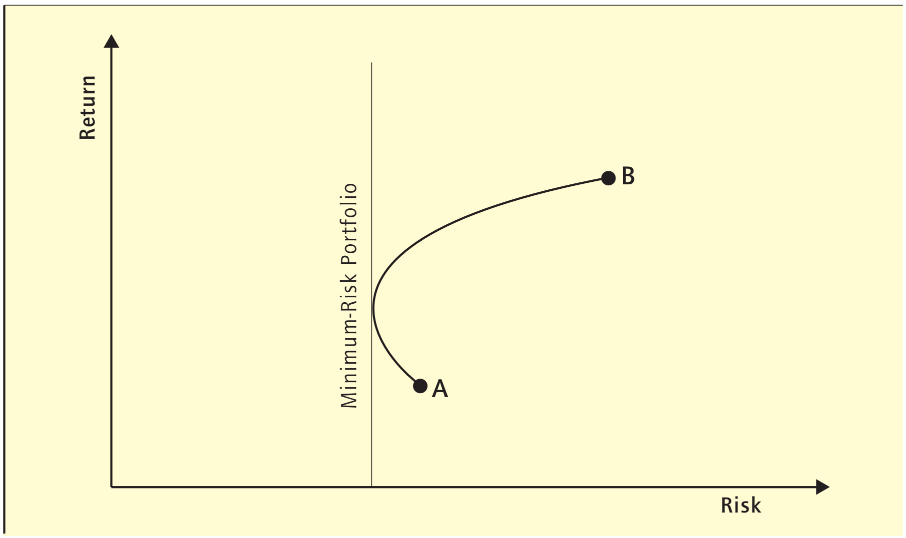


Figure 4: Reduction in risk by diversification

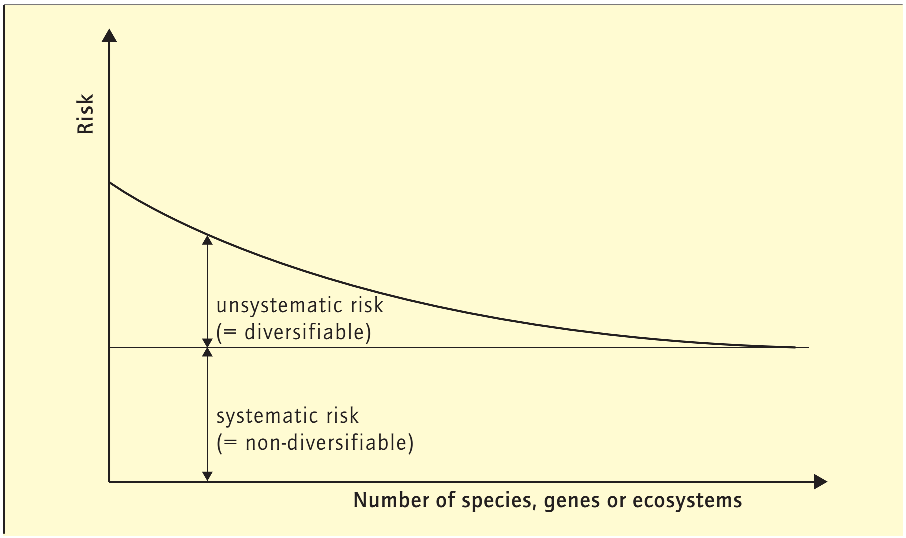
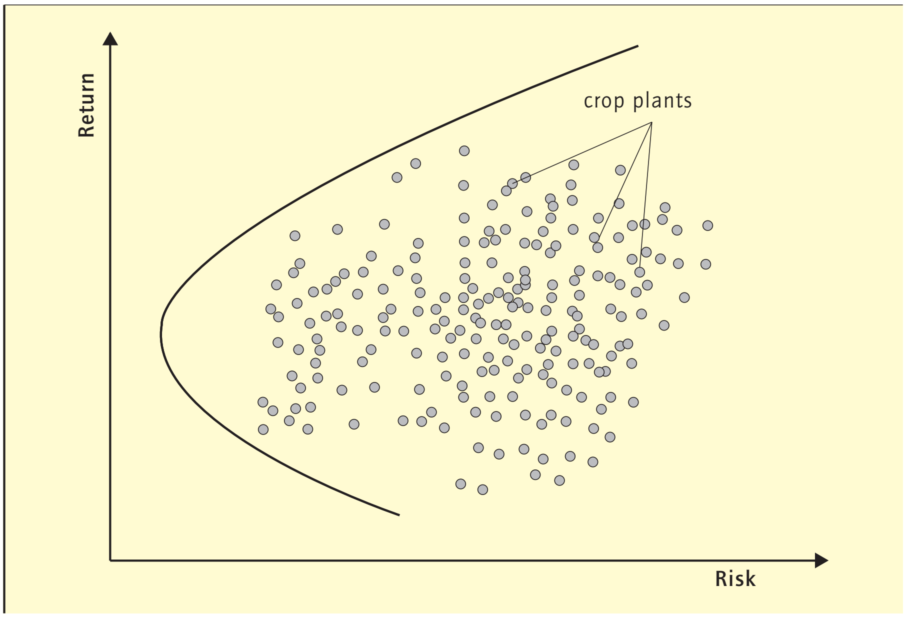


Figure 5: Return-risk relationship of a large crop-plant portfolio



A possible variation in yield for the crop-plant portfolio is illustrated in Figure 3. It resembles the pattern of line c in Figure 2.

An important risk characteristic of the portfolio can be seen in this illustration: the minimal-risk portfolio consists of both types of crop plants and not just, as might be thought at first glance, the lower-risk type of crop plant. Part of the risk can be diversified away by combining the types of crop plant. The closer the minimal-risk portfolio is to point A (B), the higher the proportion of crop plant A (B) in the crop-plant portfolio.

The risk can be reduced further

This diversification effect can be further strengthened by considering other crop plants in the portfolio. Figure 4 shows a typical progression of a portfolio risk as a function of the number of risks considered. The more elements the portfolio has, the better risks can be diversified away: the portfolio risk falls. In general, however, it is not possible to diversify away the whole risk. The curve asymptotically approaches a level of risk which it does not pass below even if the portfolio is enlarged.

An extreme drought, for example, can lead to a failed harvest. This non-diversifiable risk is also termed a *systematic risk*. The diversifiable risk by analogy is termed an unsystematic risk. An *unsystematic risk* may consist for example of a pest infestation which only threatens some crop plants.

If such a large portfolio with more than two species is transferred to the risk-return representation chosen above, the picture illustrated in Figure 5 is obtained.

As this illustration also shows, the risk can be diminished but not removed by diversification. A risk-free portfolio of this type would have to touch the yield (return) axis (y-axis). These observations can be transferred analogously to other uses of biodiversity.

It is in principle possible and appropriate to transfer portfolio theory to biodiversity. Some important differences do, however, exist between biodiversity and securities portfolios.

Limits of transferability: … symbioses

It is necessary in this context on the one hand above all to point to the significance of symbioses in the natural environment. It can be assumed in the case of stock portfolios that the decision to invest in a stock does not have any effect on the return from a second stock. Investment in one stock is not causally linked to the success of a second stock. Organisms, by way of contrast, enter into symbiotic relationships. A symbiosis or symbiotic relationship is understood as meaning “[…] organisms of different species living together to their mutual advantage” (Vogel & Angermann 1990, p. 247). If a close symbiotic relationship exists between two organisms, and if an organism is “disinvested”, the expected return from the second organism necessarily falls. This difference in comparison with stock portfolios additionally underlines the significance of forming portfolios. Symbioses can be explicitly taken into account by treating elements in a close symbiotic relationship with each other as a single element.

Systematic vs. unsystematic risks of biodiversity portfolios

Risks are not systematic or unsystematic per se, but are so in the context of the particular biodiversity portfolio concerned. A risk in principle has a systematic character if it, at the same time and in the same way, acts on many elements of a portfolio.

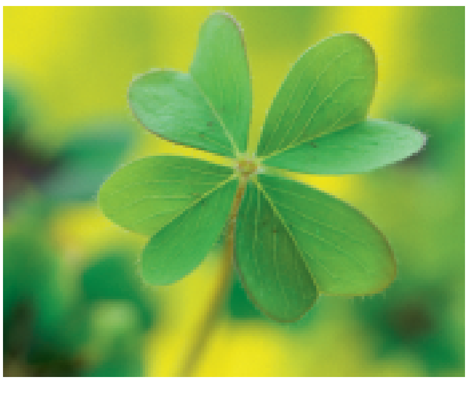
A farmer who has specialised in the production of maize is threatened, for example, by the presence of the corn borer, a typical maize pest. This risk is highly systematic for the farmer, as various maize species are threatened at the same time and in the same way. For a farmer who grows a large number of different crop plants, the risk of the presence of the corn borer is less systematic, as only a part of his crop plants, the maize, is threatened by this pest.

The occurrence of drought, on the other hand, is a systematic risk for both farmers, as both maize and other crop plants are adversely affected by drought. This is also true if the crop plants have differing drought tolerance, i.e. respond with differing intensity to drought. The risk can be reduced, but not removed, by concentrating on species which are more resistant to drought.

Pharmaceutical companies have an interest in the conservation of plants, as they hope to find new pharmaceutical active substances. Extracts are obtained from the plants for this purpose. Mendelsohn and Balick estimate the probability of a pharmaceutical preparation with a particular therapeutic action being obtained from an extract at 1:1,000,000. They additionally assume that on average six extracts can be obtained from every tropical plant (Mendelsohn & Balick 1996). The probability of being able to develop a therapeutic preparation using a particular plant is accordingly very low and the risk therefore high. The risk nonetheless has an unsystematic character: if no pharmaceutically usable extract is found in a plant species, this does not have any effect on the probability of a usable extract being encountered in a second plant species. The authors estimate the number of tropical plant species and therefore the portfolio elements at 125,000. The risk is in large part diversified away by the size of the portfolio, and the authors can make the prediction – for the whole portfolio – that 375 pharmaceutical preparations can be developed (Mendelsohn & Balick 1996).

... irreversibility

Investments and disinvestments in securities, on the other hand, are reversible. A share which is excluded from the portfolio one year can generally be considered in the portfolio again the following year. Exclusion from a biodiversity portfolio may, however, be final, that it is to say irreversible (e.g. Swanson 1992). If a species, for example, only occurs in one area and is not considered in the portfolio there, it will generally become extinct. It then cannot be considered in the portfolio again at a later time. Irreversibility should be taken into account in decisions on biodiversity. It does not, however, have any fundamental effect on the significance of portfolio considerations.



Management of biodiversity – learning from portfolio managers

Basic rules of portfolio management

Portfolio managers combine various securities into a portfolio. In doing so, they make use of the fundamental finding of portfolio theory that returns are additive whereas risks diversify. They consequently look not at the development of individual shares but at the development of the complete portfolio.

Biodiversity represents a natural portfolio of a large number of species, genes and ecosystems (e.g. Brown et al. 1993; Swanson 1997). Here too, interest must be focused on the whole portfolio.

There has been discussion for many years in the economic sciences on how portfolios are to be put together (e.g. Sharpe 1970). It is of particular interest for the management of biodiversity that consequences for the management of biodiversity can be deduced from the practice of the management of stock portfolios. These consequences, formulated here in the form of rules, are in some cases in clear contradiction with an approach which relates to individual species, genes or ecosystems and with the way in which biodiversity issues are discussed at present.

The rules are explained below in relation to both securities and biodiversity portfolios. The rules become particularly clear in the example of agricultural use. Transfer to other types of use is possible by analogy.

Weighing up return and risks

1st rule: Every decision must weigh return against risk. Additional risk must be offset by additional return.

Investors like return, but not risk. This is a fundamental assumption made by portfolio managers. It is also reflected in the behaviour of investors, who generally demand risk premiums to take on risks. As a result of this assumption, portfolio managers weigh return against risk. They are only prepared to take on additional risks if they may also expect an additional return.

This aversion to risk must also be taken into account in valuing biodiversity. A risk in this case always exists when the future benefit cannot be precisely predicted. From the economic point of view, the future benefit of all species, genes or ecosystems would probably be uncertain, that is to say show a risk. This applies regardless how it is ascertained or whether it is, for example, an expected aesthetic, pharmaceutical or agricultural benefit that is concerned. This risk is offset by the expected benefit. The higher the expected benefit, the more likely it is that the risk will be accepted.

Risks can be diversified

2nd rule: risks can be partly diversified away.

Portfolio managers combine many securities in a portfolio. This is due to a simple reason: the risks of individual shares in general partly cancel each other out if they are combined in a portfolio (cf. Section "Diversification of risks – Additivity of return"). It is said that risks diversify themselves away. Risks which can be diversified away disappear for the investor. As it is assumed that investors are averse to risks, this effect is desirable.

The mismanagement of a company is an example of a diversifiable risk of this kind. Some companies are always affected by mismanagement, but never all of them. A portfolio with many shares will therefore contain some shares in companies which are poorly managed. The risk of mismanagement disappears, however, at the level of the portfolio.

It is nevertheless not possible to diversify away all risks. Non-diversifiable risks are also referred to as systematic risks. Systematic risks arise as a result of securities being exposed to common risks, such as risks related to the economic climate. The risk associated with the economic climate therefore cannot be diversified away by forming a portfolio which is exposed to a common risk of this kind (cf. Fig. 4).

A similar relationship also applies to biodiversity. If the future benefit of a species or ecosystem is not certain, a risk exists. In the case of a crop plant, this risk may, for example, consist in the yield being decimated by an epidemic. An epidemic of this kind may represent both a systematic and an unsystematic risk. An epidemic which only reduces the yield of a single species represents an unsystematic risk. If the epidemic poses a danger to all crop plants, diversification is difficult. The risk is systematic in character (for further examples see also the "Systematic vs. unsystematic risks of biodiversity portfolios" box, p. 19).

Large landowners, countries or continents, like investors, can form portfolios by growing various species. The larger the areas which can be cultivated, the easier this will prove to be for them. As already mentioned, a positive relationship of this kind between cultivated area and decline in risk can in fact also be observed (Schurle 1996). If an unsystematic risk is concerned, this has the desired effect. It is rare for the whole portfolio to be affected by the risk. If a systematic risk is concerned, however, forming a portfolio does not provide a solution either.

This example can be extended in an analogous manner to other uses of biodiversity. Experience shows, for example, that the future pharmaceutical benefit of plant species is uncertain (Aylward 1995; Pearce & Puroshothaman 1995). Only a few of the large number of different plant species will probably be put to medical use in the future. The future yield of a particular plant species may therefore be regarded as extremely uncertain. It is highly probable, on the other hand, that some plant species in the biodiversity portfolio will be used for medical purposes. It may also be assumed that future medical use of the complete set of plant species can be predicted with greater certainty than the benefit of a particular plant species. The future medical benefit of all plant species is nevertheless uncertain. The diversification effect consequently does not allow the entire risk to be eliminated.

Benefit does not have to exceed the costs

3rd rule: The benefit does not have to exceed the costs.

A simple cost-benefit decision-making rule is repeatedly cited in connection with decisions, including in relation to biodiversity (e.g. Marggraf & Birner 1998; Plän 1999). This states that an action or a project should be carried out if the expected benefit exceeds the expected loss (e.g. Organization for Economic Cooperation and Development 1992, p. 9). This relationship only applies so simply, however, and this is often not appreciated, if either only one alternative can be implemented at the same time or no risk exists. If more than one alternative can be implemented at the same time, it is generally worthwhile forming a portfolio.[3)]

This applies to both securities and biodiversity. If the simple cost-benefit rule applied, it can be imagined that the work of portfolio managers would be simple. The portfolio would consist of only one security, the stock with the best cost-benefit ratio from the investor‘s point of view. Portfolio managers accordingly would only have to ask the financial analysis about one share, their “best tip”. Portfolio managers optimise at the level of the complete portfolio, however. To do this, they often also have to consider stocks with an apparently poor benefit-cost ratio, as these contribute to diversification.

An analogous observation applies to biodiversity. A rational portfolio manager of biodiversity also considers species which do not fulfil the classical cost-benefit decision-making rule, provided they contribute to diversification. This primarily relates to those very species or ecosystems whose yield pattern differs from the yield patterns of the other species or ecosystems in the biodiversity portfolio. This is, of course, an extremely complex task. The complexity can be reduced for example by forming classes (cf. 9th rule). As a rule of thumb, the more opposed the yield pattern in relation to the other species or ecosystems in the biodiversity portfolio is, the lower the expected benefit of a species or ecosystem may be.

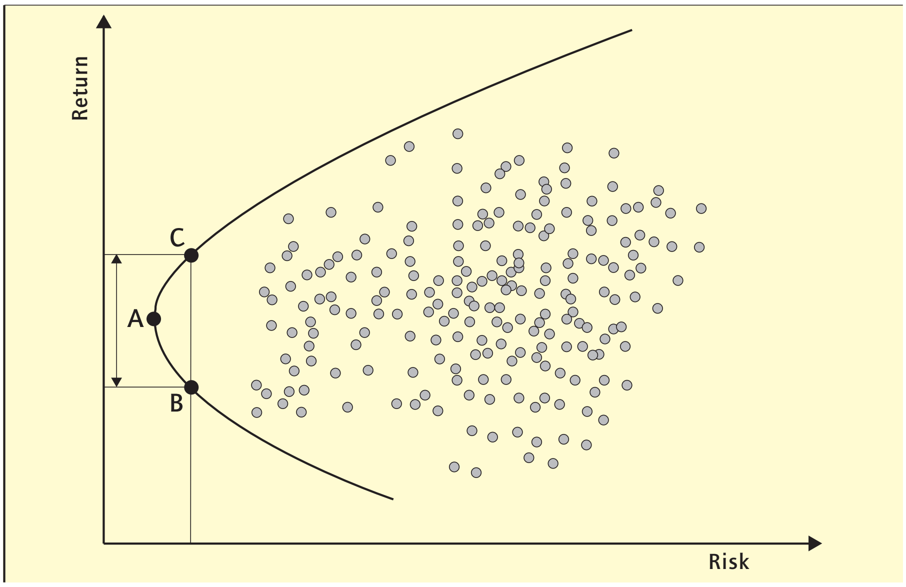
Combinations of risks are more advantageous than individual risks

4th rule: A comparable or better return-risk ratio can always be created by the combining of various elements than by an individual element of this portfolio.

Portfolio managers combine stocks in a portfolio to diversify risks, i.e. reduce them at the level of the complete portfolio. Portfolio managers in this way build up portfolios with an interesting characteristic: the risk-return characteristics of the portfolio are more advantageous than the risk-return characteristics of any randomly chosen stock or any randomly chosen combination of stocks in the same portfolio. A portfolio of this kind offers more return per risk accepted than arbitrarily chosen stocks in the portfolio.

3) It is specifically worthwhile when the risks are not correlated or are only incompletely correlated with each other.

Figure 6: Return-risk characteristics of a large biodiversity portfolio



This can be shown by Figure 6. The points stand for stocks with different return-risk combinations. The curve illustrates the most advantageous return-risk combinations which can be achieved by combining stocks in a portfolio. It corresponds to line c in Figure 2, which only took account of two stocks. The line in Figure 6 reproduces the return-risk characteristics of various combinations of the elements of the biodiversity portfolio. All the points which lie above point A on the line have a more attractive return-risk combination than individual stocks. Point A simultaneously indicates the combination with the lowest risk which can be achieved with the stocks.[4] Point B, for example, is of no interest. For the same risk, a higher return is achieved (point C) or it is even possible by skilfully combining the stocks to create a portfolio which promises higher return at a lower risk.

As a return-risk ratio superior to the return-risk characteristics of each individual security or any chosen subset of the portfolio can be achieved by combining several stocks, portfolio managers generally invest in several stocks at the same time.

An analogous relationship can also be established for biodiversity. The expected returns and risks of crop-plant species (e.g. maize, soya) are repeatedly discussed, for example (e.g. Nagi & Khehra 1996; Naylor et al. 1997). The risk in this case consists in a possible divergence from the expected return.

In principle, a species which in comparison with another species promises a higher return at a comparable risk or a comparable return at a lower risk is to be preferred. A maize species which at a comparable risk promises a higher return than a second species of maize is therefore preferred. A combination of various species will nevertheless in many cases show a better return-risk ratio than a single species. If the portfolio includes this species, a portfolio can always be constructed which shows at least an equivalent return-

[4] A lower risk and portfolios with more attractive return-risk combinations could be achieved by considering a no-risk stock or by raising loans. This expansion is not examined here, as application to biodiversity does not appear appropriate (for these expansions, see Tobin 1958; Sharpe 1964).

risk ratio. An experienced portfolio manager, commissioned to put together a maize plant portfolio, would for example resist the temptation only to include one maize plant species, even if this promised particularly high returns at low risks.

Considering low-return elements

5th rule: High-return portfolios also consist of low-return elements.

Share analysts forecast the development of share prices and make buy and sell recommendations. Portfolio managers take account of these recommendations. At first glance, they nevertheless regularly appear to ignore the recommendations of their own analysts. Sell recommendations often do not lead to the block of shares being sold and buy recommendations do not lead to a large block of the shares being bought. Portfolio managers often even retain a significant block of apparently unattractive shares. The reason for this is in the differing perspective. Analysts issue an opinion on individual shares. Portfolio managers, on the other hand, have optimising the complete portfolio in mind, and a low-return stock may certainly have a place in a portfolio of this kind. The portfolio manager estimates the effect a block of shares has on the performance of the complete portfolio. Whether a stock has a place in a portfolio therefore depends on what other stocks are already in the portfolio. As a rule of thumb, the more shares with similar characteristics are already in the portfolio and the more unimportant a stock is, the easier it is to do without it.

A similar situation applies to biodiversity. Anyone who determines the value of a species or an ecosystem in isolation adopts the perspective of an analyst. The decision on which species it is easiest to do without must be taken from the point of view of the portfolio manager. The expected yield and the expected risk of the species is just one criterion. The portfolio manager optimises the return-risk characteristics of the complete portfolio and in so doing estimates the effect of inclusion or exclusion on the return and risk of the portfolio. It may be assumed that the risk of a biodiversity portfolio is lower the more different the species in the portfolio are. Doing without low-return species, on the other hand, leads to a homogenisation of the portfolio. As a result, both the return and the risk of the portfolio generally rise (Swanson 1992). The portfolio manager therefore has to weigh up the degree of diversity and the return of the portfolio. In principle, however, a species which has a poor return-risk ratio but clearly differs from the other species may in certain circumstances be more valuable to the portfolio than a species which, although it has a better return-risk ratio, resembles the other species in the portfolio.

Caution with high portfolio return

6th rule: High portfolio returns may be a pointer to high risks.

The managers of stock portfolios have to achieve the highest possible return for a given risk. Problems can nevertheless be caused not just by portfolio performance which is too poor but by portfolio performance which is too good as well. A very poor or a very good return with a well diversified portfolio is rare, as low and high returns of the individual elements generally balance each other out.[5] Performance sharply above or below average may there-

[5] In the case of a share portfolio, this can obviously be seen in comparison with a benchmark such as a share index. In this case high outperformance or underperformance, i.e. a wide divergence, in comparison with this benchmark is rare.

fore be a sign that the portfolio manager has taken on a high risk due to inadequate diversification. It is a problem that a risk-induced above-average return of this kind may persist for several years (cf. analogously Figge 1998; Figge 2001). If professional return analysis is not undertaken, a risk-induced above-average return of this kind may provide a false incentive.

Sharply above-average returns on a biodiversity portfolio such as a crop-plant portfolio in an analogous way may be pointers to low biodiversity (e.g. genetic depletion). Greater uniformity of the returns of the individual species can be anticipated with low diversity. This represents both an opportunity (above-average returns) and a danger (below-average returns). With high diversity, on the other hand, smaller deviations are to be expected, as high and low returns of individual species offset each other. High returns in a case of this kind should therefore also be interpreted as a warning sign of a possibly high risk. Increased homogenisation of the portfolio should in any case only be adopted against an additional expected return (see Rule 1). The fact that increasing risks due to homogenisation of biodiversity portfolios is not just a theoretical danger is shown by failed harvests, which are attributed to genetic depletion (cf. for an overview Groombridge et al. 1992, p. 428).

Counting only non-diversifiable risks

7th rule: Diversifiable risks are irrelevant to the valuation. They have no effect on the discount rate.

Present-value methods have now largely become established for the valuation of shares and other securities. The present value of the expected inflows of funds is ascertained to calculate the value of a stock (e.g. Brealey & Myers 1996, pp. 12-17; Damodaran 1996, pp. 219-234; Rappaport 1999; Volkart 1998). The future inflows of funds are discounted for this purpose. The interest rate reflects firstly the time preference of the investors and secondly the risk taken. A no-risk rate of interest is therefore used to discount a flow of funds which can be predicted with certainty. If there is a risk, this rate is increased. The present value of future flows of funds consequently falls. Higher-risk stocks in this way have a lower value for the same expected returns than low-risk stocks. This reflects the aversion of investors to risk.

As portfolios cause the diversifiable, unsystematic risks to disappear, an investor therefore only has to bear the non-diversifiable, systematic risk. Only this risk therefore has to be taken into account in the discount rate. If the entire risk is diversifiable, the portfolio is devoid of risk. The expected inflows of funds in this case can be discounted at the no-risk rate of interest, although each individual stock is subject to a risk.

This also applies in an analogous manner to biodiversity portfolios and is of interest for example in the valuation of individual species for future pharmaceutical use. It is assumed that the future benefit of a species will have a lower value the more unlikely it is that this benefit can be tapped. A medicinal plant with a known action is attributed a higher value at the same expected return

than a plant whose medicinal action is not yet known. This is expressed in the application of a lower discount rate for the benefit of the known medicinal plant. This may be an incorrect valuation from the point of view of portfolio theory. The level of the discount rate depends on how subject to risk the portfolio of all medicinal plants is. The question is therefore with what probability is what benefit derived from the portfolio of all potential medicinal plants. The more certainly this benefit can be predicted, the lower the discount rate is for the use of the individual species whose individual benefit is uncertain. If the use of the complete portfolio is predictable with great accuracy, the same discount rate can be used for the expected benefit as for the benefit of the known medicinal plant.
Similar observations can also be made for the agricultural use of crop plants. Here too, a higher certainty of yield of a crop plant leads to a reduction in the discount rate and therefore to a higher value. As mentioned above, this only applies to a limited extent from the point of view of portfolio theory. If success is achieved in establishing a no-risk or low-risk portfolio of a crop plant by a suitable mixture of different species, a low discount rate can (also) be used for the portfolio of these species, although the yield of each individual species is uncertain.

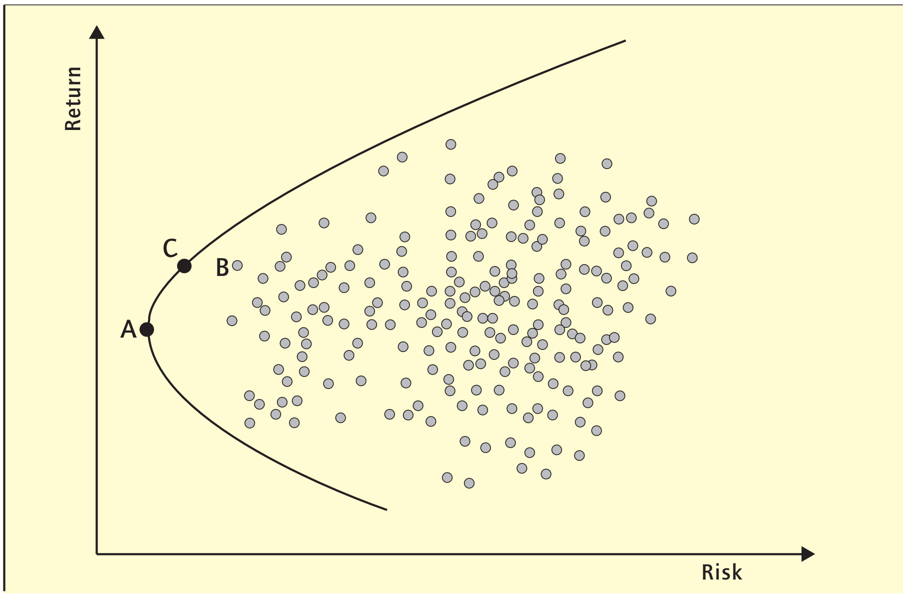
It depends on the weighting

8th rule: It is not just the number of species, genes and ecosystems but their weighting too that is of interest.

As a rule of thumb, the more different stocks are considered in a portfolio, the better the portfolio is diversified. The number of shares is, however, only one criterion of the quality of the diversification. Another criterion is the weighting of the individual shares in the portfolio. A portfolio whose value is determined almost entirely by one stock entails almost as much risk as this one stock. Equal weighting of all stocks is a way of obtaining a portfolio which is well diversified and therefore carries less risk. This type of equal weighting may, but need not be, appropriate. The characteristics of the portfolio, for example whether they entail risk, are altered by a change in the weighting of the stocks.

An analogous argument can be made in relation to various species, genes or ecosystems. In agricultural use, as high a number of different species of a crop plant as possible is desirable in principle. A portfolio of this kind is illustrated, for example, in Figure 7. The line illustrated there represents the possible return-risk characteristics of the portfolio. In principle, the more crop plants the portfolio has, the closer it comes to the y-axis, the lower the risk is (cf. also Fig. 4 and Rule 4). Point A in Figure 7 can be reached with optimum, that is to say risk-minimising weighting. If the portfolio shows substantial overweighting of a species, however, the diversification is insufficient; the portfolio has an unnecessarily high risk. Point B, for example, represents the return-risk characteristics of a portfolio of this kind. Point C can be reached by expanding the portfolio and weighting accordingly. This point shows a lower risk at the same expected return.

Figure 7: Return-risk characteristics of a crop-plant portfolio depending on the weighting of the species



Transferred to a crop-plant portfolio, this means that it must not only be ensured that a sufficient number of different crop plants exist but that they must also be weighted accordingly. The existence of a species in a portfolio is not sufficient.[6)]

Not just the number of species, genes and ecosystems but their weighting as well must therefore be considered in the valuation of biodiversity.

Reduction in complexity by forming classes

9th Rule: Efficient asset allocation can be ensured by class formation.

A portfolio manager can resort to a virtually unlimited number of stocks to build up his portfolio. In practice it is impossible to consider all possible securities in the decision. A portfolio manager has to ensure at the same time, however, that the portfolio has as attractive a return-risk ratio as possible. Portfolio managers therefore have to reduce the complexity of the decision-making situation. This is achieved by combining securities with similar characteristics in classes (Bruns & Meyer-Bullerdiek 2000, p. 128). Securities may belong to more than one class. They may be classified, for example, according to sectors, countries or currencies. It can be ensured in this way that a portfolio always shows diversity in terms of sectors, countries and currencies. It is presumed, and this represents an appropriate assumption, that the stocks within a class develop similarly and contribute little to the diversification of a portfolio. After it has been decided how strongly a class of stocks overall is to be considered, stocks where appropriate can be selected within the sector, country and currency classes.

The manager of a biodiversity portfolio faces a similar challenge. He has to build up a portfolio which is as valuable as possible. The

[6)] The pharmaceutical use of species could represent a special case in this context. It may be sufficient to consider one specimen of each species in the portfolio as a second specimen may not promise any additional benefit for pharmaceutical use.

large number of species, genes or ecosystems does not, however, allow any simultaneous consideration of all the possible elements in his deliberations. An option is therefore to combine elements with similar characteristics in classes. The desired weighting of these various classes can then be decided upon in a higher-level decision. The loss of a species, for example, is accordingly easier to cope with the more species there still are in its class. In a corresponding way, the loss of a species weighs all the more heavily the more species in this class have already become extinct.[7]

It has been shown in the management of stock portfolios that a top-down procedure of this kind often provides a higher contribution of value that "stock-picking", that is to say the selection of individual shares (Brinson et al. 1991; Hensel et al. 1991).

[7] It obviously cannot be concluded from this that a decline in species within a class is desirable. A decline in species within a class obviously leads to depletion of this class.

"The application of portfolio theory to biodiversity management is a distinctly sustainable approach, particularly as values change and new developments are to be expected. Precaution and future orientation are as much part of the insurance business as the clear understanding of historical events. Learning from the past for a better future is a key aspect of the conservation of biological diversity." GSDP, 2002

Summary and outlook

Whenever decisions relate to a complete pool of elements and the return on the individual elements cannot be predicted with certainty, portfolio theory can be appropriately applied. Biodiversity is such a case.

It is assumed in the economic sciences that decisions are determined by the expected yield and expected risk. This is also true of portfolio theory. If the decisions relate to complete portfolios, it is not the return and risk of each individual element that are of interest, but those of the complete portfolio. Decision rules, which relate to the individual elements, can then lead to incorrect decisions. A prominent example in this context is the rule that for a species to be conserved its benefit must exceed the costs.

Viewing in isolation leads to incorrect decisions

Viewing in isolation in this way is not the exception but the rule in the context of the discussion of biodiversity. This is surprising, because in comparable situations a portfolio view is adopted in the theory and practice of economic sciences.

This includes, for example “asset management” among financial service providers. Professional asset managers separate the functions of analysts and portfolio managers. Analysts determine the value of a company or a stock. The decision on what alternatives are considered in a portfolio is taken by portfolio managers, however, and because they are geared towards the success of the complete portfolio, they often also consider companies which are classified by the analysts as unattractive.

No such separation has been made to date in relation to biodiversity, either in theory or in practice. This leads to a notable consequence: share portfolios today are managed more professionally than the natural environment.

Positive and normative contribution of portfolio theory

Portfolio theory makes both a positive and normative contribution for both stock portfolios and biodiversity portfolios. It firstly uncovers the relationship between the return and risk of individual elements and the return and risk of complete portfolios. Portfolio theory consequently makes available the information portfolio managers require to manage their portfolios effectively. Secondly specific instructions for action to achieve successful portfolio management can be derived from it.

Portfolio theory has strongly influenced the way in which stocks are managed. Before portfolio theory was developed, there was only a vague notion that diversification improves stock portfolios (Bitters 1997, p. 55). The development of portfolio theory led to a re-orientation of the previously little-structured portfolio management (Kleeberg & Schlenger 1995, p. 441). This step has yet to be taken for the management of biodiversity.

The aim of this study was to provide an introduction to the transfer of portfolio theory to biodiversity issues. There are three important possible development openings on the basis of this study.

Firstly, a general transfer which extends beyond the largely qualitative transfer of portfolio theory to biodiversity issues undertaken here should be considered. Secondly, the relationship between risk and value of biodiversity should be investigated more closely. As this study has shown, the distinction between systematic and unsystematic risks is of great significance in this context. In the economic sciences, use is generally made of the Capital Asset Pricing Model (CAPM) (Lintner 1965; Mossin 1966; Sharpe 1964) to establish the relationship between (systematic) risks and the value of securities. An alternative model, the Arbitrage Pricing Theory (APT) (Ross 1976), presents itself for biodiversity, however. While the CAPM is restricted to a single (systematic) risk factor, the APT permits several risk factors. Application of APT to biodiversity can show what risks have a value-reducing effect and therefore provide important information for the optimum composition of biodiversity portfolios. Thirdly, issues of portfolio management should be examined more closely. Portfolio theory establishes the relationship between the return-risk characteristics of individual elements and the return-risk characteristics of portfolios. Portfolio management has the task of putting together portfolios in such a way that they meet the preferences of the portfolio holders as well as possible. Institutional issues, for example, are also to be clarified in this context.

Homogenisation of the elements of a portfolio leads to an increase in risk, without the expected return and expected risk of the individual elements having to change. This leads to an increase in risk due to systematisation of risks often remaining unobserved (Figge 1998; Figge 2001). It is unlikely, however, that a development of this kind can be discovered from an analyst‘s perspective. The consequences of homogenising investment opportunities has been a topic of regular discussion for a number of years in the financial market (e.g. Brooks & Catao 2000). The management of biodiversity lags a step behind: the step from an analyst‘s to a portfolio manager‘s perspective has yet to be taken.

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