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Sustainable environmental and natural resource economics

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Introduction

Sustainable development strategies are gradually becoming the core of economic policies of nations and international organisations, although in many cases only in declarations. The quality of environment and the integrity of natural wealth of our planet are decisive for the quality of life. Man is an integral part of the biosphere which constitutes our only life-support system in an otherwise hostile cosmic environment. By threatening its integrity and functioning, we are not only seriously affecting the quality of human and other life, but we may even be threatening the very existence of life on Earth. Even though more than forty years have passed since the Stockholm Conference on the Environment (1972) and despite the Brundtland Commission's explicit warning that human activity was disrupting the ecological life-support systems to the extent of approaching the "thresholds of human survival" (WCED, 1987), policy-makers have not even begun to address the issue in its extreme gravity.

The systems of production and consumption in market economies, based largely on the paradigm of neoclassical mainstream economics, combined with the negative environmental impacts of former centrally planned economies and the impacts of poverty in non-industrialized countries have resulted in a variety of patently unsustainable and threatening effects, including global climate changes, depletion of the stratospheric ozone layer, acid rains, deforestation, soil erosion, species extinction and toxic pollution.

As the foremost thinkers of our current world show, humans are facing a wide range of global problems, which are systemic problems, mutually tied and interrelated. The quantum physicist and philosopher Fritjof Capra notes that "*The extinction of animal and plant species on a massive scale will continue as long as the Southern Hemisphere is burdened by massive debts...There are solutions to the major problems of our time; some of them even simple. But they require a radical shift in our perceptions, our thinking, our values.*" (Capra, 1996, p. 3-4).

Similarly, Hawken, Lovins and Lovins, the authors of an important book on the shortages of current market economies write: *"Capitalism, as practised, is a financially profitable, nonsustainable aberration in human development...It liquidates its capital and calls it income. It neglects to assign any value to the largest stock of capital it employs - the natural resources and living systems, as well as the social and cultural systems that are the basis of human capital."* (Hawken, Lovins, Lovins, 1999, p. 5)

The aim of this textbook is to describe and explain the methods for valuing the environment and the complex relations between the economy and the environment. The unifying theme of this study is the explicit recognition that economic system is a subset of the physical world. Any economic decision-making or any decisions about the environment must respect the constraints that exist among natural environment and economic systems. Around the world you can find dozens of textbooks on economics and on the environment. However, few of them address the problem of integrating the economy and environment from the viewpoint of practical decision-making processes. Economy, society and the environment are linked together in an evolutionary network. A real integration of economic systems with the environment can only be based on the real market and non-market valuations of natural and environmental resources. This textbook intends to contribute to broader knowledge of the market and non-market valuation methods.

Natural resource economics (established already in the first half of the 19th century) and much newer environmental economics (developed in the second half of the 20th century) have tended to be treated as separate and autonomous disciplines of neoclassical mainstream economics. The practical needs of the current globalized world and a growing scientific knowledge argue that these two disciplines should be treated as a unified discipline.

Natural resource economics that was formed gradually over the last two centuries deals with the utilitarian question how to use a natural resource in order to obtain a maximal net benefit. Traditionally, it includes agricultural and forest economics, the theory of optimal resource extraction for non-renewable (exhaustible) resources, and economics of urban land. Overall, natural resource economics systematically describes a rational and economically optimal use of a natural resource viewed from the standpoint of the user (owner).

The past several decades witnessed the proof that the environment and its resources are important not only for economic welfare, but that they are much more important as life-supporting ecosystems (the terms *environment* and *nature* are treated in this study as synonymous). The biosphere of the Earth is not only a source of natural resources for production and consumption, but also an environment which enabled the birth of human species and the birth of millions of other plant and animal species. The growing scarcity of such life-supporting services of ecosystems must become an organic part of natural resource and environmental economics and, more generally, a part of economics. The reason for this is that only by incorporating the environmental services into economics and economic decision-making processes people can find the equilibrium among the economic and ecological functions of the environment and implement one of the important principles of sustainable development.

Environmental economics is focused on identifying the optimum level of environmental pollution and it treats the economic efficiency of environmental protection. The majority of the existing approaches to environmental economics treat pollution as only a flow of polluting matters. This substantially limits the economic analysis, as almost all forms of pollution have a stock dimension too. Damages to the environment are related to the stock level of the pollutant in the environmental medium.

Similarly, economic theory is often understood as the analysis of economic behaviour of people when assuring their material needs. In other words, economics is explained as a study of an effective allocation of production factors in maximizing production results. The production factors are labour, capital and mainly the natural resources that come from the environment. At the same time, it is known that in standard economics the factor of land has been marginalized for decades. For example, even during the 1970s in many models of economic growth the input of environment was completely omitted and production results were analyzed as dependent on only labour and capital. However, among the production factors all forms of environmental use must be included together with all the externalities caused by such economic activity. The production factors must incorporate also the use and destruction of environmental services produced by ecosystems. The overall aim of this textbook is to show that only by integrating the approaches of all these three scientific disciplines we can contribute to a sustainable economic theory and to sustainable economic systems.

Chapter 1. Brief history of economics and nature pricing

1.1. Economics, natural and environmental resources

If economics is generally understood as the study of the allocation of limited resources to satisfy human wants and desires, then it is first of all necessary to define the term ***resources***. In many standard economics textbooks the term resources is used synonymously with the factors of production (inputs without which the production could not take place). Economic analysis typically adopts the premise *ceteris paribus*, which means *other things being equal.* Similarly, for any given state of technology, the relation between some quantity of production and some quantities of economic resources can be expressed by a production function as a mathematical relationship between these two entities

$$Q = f\,(X_1, X_2, \ldots X_n) \qquad (1.1)$$

where Q = maximised quantity of output flow for given values of the arguments of production function and given quantities of n productive inputs or factors X.

Since the times of classical English political economy, it is common to identify three distinct classes of production factors, namely L, C, and M, denoting respectively quantities of **labor, capital** and **land**. In applied empirical analyses sometimes a fourth factor **energy** E is applied. These production factors enter into production function either as flows of services over some period of time, or as stocks employed at some point in time. Production function can then be formalised as

$$Q = f\,(L, C, M, E) \qquad (1.2)$$

Is the above mentioned classification of production factors sufficient from the viewpoint of economics and economic decision-making? The answer to this question depends on the level of complexity these production factors are debated at. **Under the notion of land** sometimes only a space or territory is understood, sometimes soil fertility from the viewpoint of agricultural or forest production. Nevertheless, neither the former, nor the latter notion is sufficient, because land, i.e. the nature and its resources, serve not only as a source of natural resources for human economic activities, but due to their growing scarcity increasingly also as a **life-supporting environment**. These life-supporting functions or services of the environment and its ecosystems (clean air, water etc.) were and often as yet are used by people as free, zero priced services.

In general, environment services comprise:

1. direct provision of economic services with direct use value (production of food, fibres, extraction of fossil fuels etc.)
2. human and industrial waste assimilation by natural ecosystems
3. direct provision of environmental inputs (such as clean air and water, landscape amenities, aesthetical values)
4. environmental system maintenance processes, i.e. the processes of conserving and regulating the ecosystems that sustain and clean the air and water, maintain climatic conditions, regulate chemical composition of the atmosphere and oceans, regulate soil fertility, fixate solar energy and converse into raw materials, store and recycle nutrients and food cycles, maintain and support the stock of renewable resources (fish, biomass, regulate water flows in river systems etc.) and provide the life-supporting environment.

The main problem is that people are over-using the first two economic functions of environment at the expense of the other two ecological functions, which are decisive for sustaining life.

One of the main axioms or principles of economic theory says that resources are scarce (in other words, resources are limited). The scarcity of resources means that the resource demand outstrips supply (insufficient availability of a resource to satisfy human needs or wants). The scarcity of resources implies that their use is costly, they have a positive price. The use of a scarce resource has an opportunity cost in the form of an alternative foregone benefit. In those cases where a resource user directly incurs this opportunity cost, the cost is known as private cost. However, in many cases opportunity cost is borne by other persons (for example in the case of polluting emissions). These costs are known as external costs (externalities, see Pigou, 1920). The full cost of the resource use is composed of private and external costs.

Many resources can be used as private resources (can be possessed and owned by an individual) under well-defined property rights. From the viewpoint of environment, in market economies these were traditionally natural resources that were privately owned (agricultural land, forests, mineral deposits etc.). At the same time, there have been many environment services that are not priced and used as free public goods (clean air for breathing, climatic conditions with favourable temperature, constant composition of air etc.). These resources, often described as environmental services, are useful and irreplaceable as the existence condition for all living forms. However, as free public goods they do not enter into production functions as production factors.

As an example of environmental resources, natural ecosystems can be mentioned as well as all their plant and animal species. Around the world, there are approximately 1.5 million of plant and animal species identified. By incorporating insects, this figure increases from 5 to 30 million species. Only a negligible fraction of percentage is directly used by humans and more than 99.9 % remain beside direct use. Their contribution for human society and contribution in ecosystems is so unclear but so deeply tied in living networks that it is hard to estimate their individual values.

There are many classification schemes of environmental resources. One fundamental property concerns the reproducibility of a resource stock (rates of regeneration). Resources with high rate of regeneration are renewable, otherwise the resource is non-renewable (exhaustible). This distinction is useful but limited, because renewable resources are also exhaustible in case that the rates of using the resource are relatively high (higher than the rate of reproducibility). Such classification scheme, as shown on page 15, has the advantage that it enables us to view pollution and over-using of environment as a form of environmental resource depletion, in so far as pollutant flows result in reductions in the quantity and quality of one or more environmental resources.

Natural resource economics has a history of about two hundred years, while environmental economics started only in the second part of the twentieth century. An important characteristic of both these scientific disciplines is their eclecticism. They draw their techniques largely from the field of pure and applied economic theory and they had incorporated only some elements from natural sciences, system analysis and ethics. But both disciplines are far from having achieved a synthesis of these components. That is why it will be useful to say something about the history of economic theory alone.

1.2. Brief history of economics and nature pricing

The interest in economics, i.e. the interest in how people are ensuring their basic human needs, is as old as the human civilisation itself. It is possible to say that since a long time ago people have been mainly pricing those natural resources that had brought them some direct economic benefit. Primarily it was the space alone, the territory and its parts – grounds for construction, agricultural lands, forests, water resources and deposits of mineral resources.

Economics started to be formed systematically at the beginning of the industrial revolution two or three hundred years ago under the influence of the depletion of traditional natural resources.

The advent of the industrial revolution (which put an end to the several hundred year history of the feudal system), tied with enforcing the freedom of a human individual, brought a change to the ethical-institutional system of values, which meant a radical turn in the moral rules for economic activities.

The medieval value system of European nations originated in the idea of the holiness of natural world, in the moral barriers against lending money for interest, and in the conviction that personal profit and accumulation should be hampered, that work is devoted to the benefit of a group (collective, community), that trade is substantiated only for the renewal of abundance for society and that the real rewards are awaiting in the other world. In all early societies, the principle of household economy, from the Greek *oikonomia*, played a substantial role. Private property was substantiated only to the extent that served the welfare of all. The word “private” comes from the Latin *privare* (deprive sb of sth), which shows an enlarged medieval opinion that property should be first and foremost common (F. Capra, 1983).

Up to the 17th century, people did not meet the economic phenomena alone, separated from life. Only in the 17th century the nation-wide markets spreaded (production for an anonymous consumer) to all over the world. As soon as individual nations (national communities) started to leave the shared ownership (common property, municipal ownership) and started to hold more individualistic opinions, people ceased to perceive private ownership as a damage (detriment) to community and a contrary approach started to be preferred, stemming from the position that private property should create the basis and the individual should not be deprived of his/her property by society without proper legal process (F. Capra, 1983).

A breakthrough turning point in the moral codex for economic activities, consisting of the abandonment of the moral duty of an individual toward his/her community and toward common property and founding the new, self-interested orientation of individuals was expressed in the work of **Adam Smith** (l723-l790), who is considered the father of modern economics and the founder of classical political economy. Adam Smith introduced the ideas of self-interest and of an invisible hand, i.e. the ideas that an economic system that relies on a free market and on free self-interested individuals tends to a natural state of ultimate welfare.

In his major work “An Inquiry into the Nature and Causes of the Wealth of Nations” (1776), Smith expressed and confirmed the belief in the predestined harmony of interests in the conditions of a free competition and the belief in the efficacy of invisible hand (i.e. the belief in the efficacy of the market mechanism) that regulates economic activities in a way leading to a state general equilibrium among demand and supply:

"*As every individual, therefore, endeavours as much as he can both to employ his capital in the support of domestic industry, and so to direct that industry that its produce may be of the greatest value; every individual necessarily labours to render the annual revenue of the society as great as he can. He generally, indeed, neither intends to promote the public interest, nor knows how much he is promoting it…he is, in this as in many other cases, led by an invisible hand to promote an end which was no part of his intention…By pursuing his own interest he frequently promotes that of society more effectively than when he really intends to promote it*" (Smith, 1776, Book IV, Chapter 2, p. 477).

However, Smith's confidence in the "laissez-faire" liberal system was not boundless, because he was conscious of the possibilities of unfair distribution of resources and incomes even in the conditions of relative economic freedom. Let us note that also many later thinkers proved that the "laissez-faire" principle does not secure the protection of human freedom. For example, the Frenchman Lacordair wrote in 1848: "*In a system which produces an unevenness of power and wealth, freedom mutes (restrains) and law liberates"*; similarly e.g. Riviere, 1932: "*Economic freedom, according to the conception of liberals, is a freedom for strong individuals, so that they could repress weak ones"* (see E. James, pp. 142, 143).

Generally it can be said that the doctrine of invisible hand (the doctrine of free market) has been since the 19th century accused of being a bad guidance for solving social problems, and it concerns in the first place the relations among society and nature.

The classical English political economy differentiated the concept of *land* as one of the three basic production factors (beside labour and capital, to which presently sometimes energy is also added). Land is understood not only as space alone, but also as all other natural resources (woods, mineral deposits, water resources, e.g. water head etc.).

Because land and other natural resources were understood as the factors of production, it was natural to appreciate their economic utility stemming from the services which these factors could bring in production and consumption. The evaluation of natural resouces according to the flow of their future services (benefits) was the original and the most natural pricing method. It was not a natural resource itself which has been valued, but the sum of its economic effects (services) from its exploitation. According to the original Judeo-Christian teaching, God intrusted people with nature to their usage. According to some other cultures, man does not stand above nature, but is a part of nature.

Early classical economists took land as fixed and, due to the diminishing returns, they saw bad prospects for future generations. This thesis was most strongly argued by **Thomas Malthus** (l766-l834). Given a fixed land quantity and an assumed continual positive population growth, the diminishing returns in agriculture imply a tendency for the output per capita to fall over time. That is why Malthus was sceptical in a long-run tendency for living standards. At the same time this English priest and thinker supposed that before the exhaustion, the limit of natural resources does not enter into economic decision-making processes.

The modern views on scarcity of natural resources have their roots in the work of David Ricardo from the first half of the 19th century. **David Ricardo** (l772-l823) approached the problem of scarce sources differently from Malthus, because he started from the assumption that the highest quality sources are exploited first and gradually the interest passes to the less high quality sources. Such gradation entails that from the beginning, scarce resources enter in his considerations. At the same time he presumed that economic development proceeds in such a way that the economic surplus is appropriated increasingly in the form of rent as return to land (i.e. will accrue to land owners). That is why, analogous to Malthus, he regarded the possibilities of a long-term economic development sceptically (the development converges toward the Malthusian stationary state).

Ricardo's theory of rent creates probably the most important part of his main economic work, "Principles of Political Economy and Taxation" (1817). The statement that the problem of land use (use of natural resources) was central for Ricardo is proved in the text of his main work, which starts by the following (Ricardo, 1956, p. 7):

"The produce of the earth – all that is derived from its surface by the united application of labour, machinery, and capital, is divided among three classes of the community; namely, the proprietor of the land, the owner of the stock or capital necessary for its cultivation, and the labourers by whose industry it is cultivated.

But in different stages of the society, the proportions of the whole produce of the earth which will be allotted to each of these classes, under the name of rent, profit and wages will be essentially different; depending mainly on the actual fertility of the soil, on the accumulation of the capital and population, and on the skill, ingenuity, and instruments employed in the agriculture. To determine the laws that regulate this distribution, is the principal problem in Political Economy."

In Ricardo's theory, there are two reasons for rent: unequal fertility and scarcity of land. Differences in fertility were the inspiration for his *differential rent* ("If all land were equally fertile there would be no rent. Rent is not the result of the generosity of nature but of her niggardliness."). The second reason for rent was the scarcity of land. If land was homogenous in quality, the limitations of supply would create only *scarcity rents* (Hubacek, K., van der Bergh, J.C.J.M., Ecol. Econ. 56 (2006), p. 9).

In his work Ricardo adds (Ricardo, 2001, p. 54 and 56):
"Rent is those part of soil produce that is paid to the proprietor of the land for the use of original and indestructible forces of the land… Rent is paid for the use of land because it is scarce and of unequal fertility and because in the progress of population, land of aninferior quality, or less advantageously situated, is called into cultivation. It is only, then, because land is not unlimited in quantity and uniform in quality, and because in the progress of population, land of an inferior quality, or less advantageously situated, is called into cultivation, that rent is ever paid for the use of it... When in the progress of society, land of the second degree of fertility is taken into cultivation, rent immediately commences on that of the first quality, and the amount of that rent will depend on the difference in the quality of these two portions of land".

The above mentioned principles of rent generation are respected by economic theory up to the present days as fundamentals of natural resource economics.

John Stuart Mill (1806-1873) is also included among classical economists. His greatest economic treatise "Principles of Political Economy and Taxation" was for the first time made public in 1848. This work is considered by contemporary specialists on history of economic teaching as "a final synthesis of Ricardian doctrine" (Blaug, 1985). While classical economists overestimated the role of diminishing returns, Mill judged its role more realistically. He appraised economic progress as a competition among the technical progress and the diminishing returns in agriculture. Nevertheless, he also assumed that economic growth must in the end, from the long-term standpoint, enter in a stagnation stage. Mill also realized that land is not exploited only for agricultural production and mining of natural resources, but that it is also used as living environment and offers esthetical values to man. Some of Mill's ideas are surprisingly topical today:

"I confess that I am not charmed with the ideal of life held out by those who think that the normal state of human beings is that of struggling to get on; that the trampling, crushing, elbowing and treading on each other's heels which form the existing type of social life, are the most desirable lot of human kind, or anything but the disagreeable symptoms of one of the phases of industrial progress…Those who do not accept the present very early stage of human improvement as its ultimate type may be excused for being comparatively indifferent to the kind of economic progress which excites the congratulations of ordinary politicians: the mere increase of production…It is only in the backward countries of the world that increased production is still an important object; in those most advanced, what is needed is a better distribution…If the earth must lose great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger, but not a happier or better population, I sincerely hope, for the sake of posterity, that they will be content to be stationary long before necessity compels them to it." (Mill, 1857, Book IV)

Classical economists, who stayed relatively pessimistic in the question of the possibility of a long-term growth, did not treat only the impact of land scarcity on the long-term development. Another problem for them was the fixation of prices or setting the values of different reproducable commodities. Emanated at the same time from labour theory of value, according to which price and value are determined by the quantity of work necessary to create specific commodities (value and price are determined by the production costs).

The modes and efficiency of nature use in former centrally planned economies were under a heavy influence of Marx's economic theory. **Karl Marx** (1818-1883) developed the labour theory of value of classical economists with the ideological goal to prove that the only one source of economic value is the "productive work of labour". Contrary to Ricardo (who respected price formation according to labour with only reproducable goods), Marx ascribed to labour theory of value general validity (which, logically under his doctrine, he had to do because normally land prices are formed on the basis of their useful services and not under labour input). He called the rent from land "the false social value", derived as a difference among market price (regulated by the production costs in the worst natural conditions) and the real average social production costs.

Marx supposed that after removing private ownership, the future society can produce the products of nature with only the real production costs, i.e. he supposed that the rent as a price of land can be removed from the production costs. It means that he supposed natural resources can be used as free goods.

In centrally planned economies, Marx's doctrine about the possibility of a free usage of nature was made real. At the beginning, the realization of this doctrine seemed to be an advantage of the socialist system (because it was possible to use the products of nature with prices that were lower compared to prices that included rent). But after a relatively short period it was proved that it had negative impacts. The elimination of rent from the price system led to wasteful use of natural resources and very often to enormous devastation of nature and environment.

The ideological reasons for such unfortunate relation to nature were obvious. They were grounded in the refusal of rent as something which is false and antisocial. But in reality, the concept of rent fulfils not only the function of income distribution (which was treated by Marx as decisive) but also the function of balancing the supply and demand of natural resources. If the rent part is expelled from price creation and prices are created only according to the average costs of production, as it was in centrally planned economies, an economic system is facing a permanent overuse of natural resources.

While classical political economy saw value as arising from the labour power embodied (directly or indirectly) in output (i.e. it was concentrated on the supply side only), neoclassical economics (that creates the economic substance of Western civilization) envisaged value as being determined in exchange by the utility or scarcity of resources (looked at price from the demand side).

Neoclassical economics that was formed since the 1870s [**S. Jevons** (1835-1882), **K. Menger** (1840-1921), **L. Walras** (1834-1910), **A. Marshall** (1842-1924)] introduced a new concept of value as an expression of marginal utility. This paved the way for the development of welfare economics, in which values could be measured in terms of consumer preferences. This school assessed the problem of using natural resources as a part of a general system of using scarce resources. The classical problem of absolute scarcity was replaced by a relative concept of scarcity. Exhaustion of natural resources was not treated for a long period as a serious economic problem (and many economists in market economis still hold a similar approach even now), because, according to its principles, with the growing resource scarcity the price is growing as well, which stimulates looking for cheaper substitutes. Many neoclassical growth models are characterized by the absence of land or any wider category of natural resources from the production function underlying growth models.

Neoclassical economics approached nature from the utilitarian positions (utilitarianism evaluates natural resources from the viewpoint of their benefits for human individual or for society as a set of individuals), i.e. it approached nature as only a base of natural resources exchanged on markets and it was not concerned with non-market functions of nature. The original investigation of optimal depletion of exhaustible resources dates back to L. **Gray** (1914) and especially H. **Hotelling** (1931):

"Disappearance of world's reserves of mineral sources, woods and other exhaustible sources led to requirement of regulation of their exploitation. Conviction, that these products are now too cheap for welfare of future generations, that are selfishly exploited in instant rate and that in consequence of their excess cheapness are wasted in production and consumption, put origin of protectionist movement."

Gray and Hotelling provided a foundation upon which a more general and extended structure was built later by P. Dasgupta, G. Heal, R. Solow and Hartwick, who developed models of efficient and optimal use of exhaustible and non-exhaustible natural resources (Nedoma, Seják, 1992). The basic principles of natural resource valuation and pricing are outlined in the next parts of this chapter and in more details in Seják et al., 1999.

The paradigm of neoclassical system (especially welfare economics) upon which the current natural resource economics is based is individual utilitarianism and libertarianism, i.e. an approach to human individual as a free and rationally acting individual (with his/her individual rights and liberties undisturbed) who maximizes his/her own self-interest. The basic neoclassical libertarian approaches come from the axiom of minimal state, i.e. they want the state to intervene on free markets only in the cases of a market failure, i.e. when a market does not ensure an optimal allocation of resources.

Neoclassical theory came from the conception of A. Smith who understood economics as a study of demand and supply that governs the distribution of scarce resources by free markets without any regulating interventions. While English classical political economy was understood by the representatives as a historical science (economic laws are changing with changes of economic system), neoclassicists ceased to respect the historical basis and started to explain neoclassical principles as universally valid timeless concepts. Due to this approach, neoclassical economics became only a formal framework (e.g. Walras theory of general equilibrium) that was unable to reflect real problems of real economy.

Only during the 20th century economists revealed that markets can assure optimal (efficient) allocation of resources just in the very specific conditions of perfect competition that are characterized by the following institutional arrangements: 1) markets exist for all goods and services, 2) all markets are perfectly competitive, 3) no externalities exist, 4) all goods and services are private goods, there are no public goods, 5) property rights are fully assigned, 6) all transactions have perfect information, 7) all firms are profit maximisers and all individuals utility maximisers, 8) long-run average costs are non-decreasing, 9) transactions costs are zero, 10) all relevant functions satisfy convexity conditions (Perman, Ma, McGilvray, 1996, p. 93).

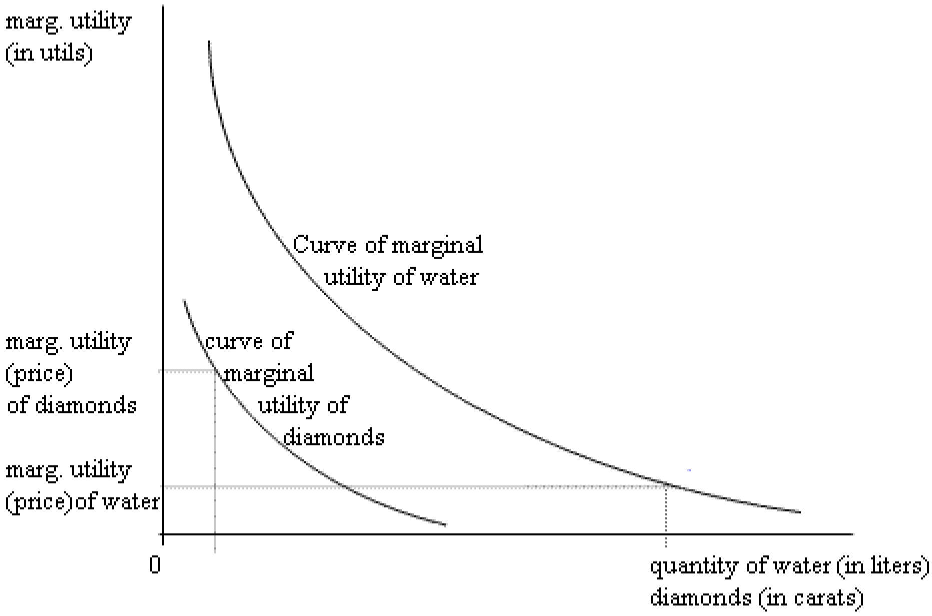
On the basis of the above quoted institutional arrangements (that originally were implicit) and on the basis of marginal utility theory, neoclassical economics resolved the paradox of price and value which puzzled classical economists. This paradox can be expressed by the following question: Why should the price of diamonds exceed the price of water, if water is more valuable? Should it not therefore command a higher price? Adam Smith for this reason differentiated between use value and exchange value. Neoclassicists resolved the hundred year dilemma by the concepts of total and marginal utility. In standard neoclassical textbooks we can obtain the following explanation:

"The key to the puzzle is scarcity and how it affects marginal utility. Water is cheap because it is so abundant. Another gallon provides little additional utility. Therefore, consumers are willing to pay very little for the extra water. In contrast to water, the supply of diamonds is extremely limited. Because the value or utility of an additional diamond is high, consumers are prepared to pay a high price for it. Of course, the degree of scarcity may change over time and, as it does, so will marginal utility of an additional unit. Other things equal, a scarcer a good becomes, the higher its marginal utility and therefore its market price." (Ragan, Thomas, 1993, p. 589)

The paradox of value and price was resolved in such a way that total value was given by total utility (total use value) while the exchange value and price depend on marginal utility, not on total utility. Neoclassical economics comes from the assumption that any individual maximizes his/her utility and that this utility can be measured. Total utility is given by the cummulative satisfaction obtained from all consumed units of the goods (the sum of marginal utilities from all consumed units of the goods) while marginal utility (and price) is measured by the satisfaction flowing from the last unit consumed. While total utility grows with the growing number of goods consumed, marginal utility from any other unit of goods consumed is lower.

The key to the resolution of classical problem, i.e. what the basis of price is, was found by neoclassical theory in scarcity. Because water is plentiful, people are willing to pay little for it (low price). The scarcer the goods becomes, the higher is the willingness of people to pay for it. Although water is essential to life and has high total value or total utility, its price is not determined by average utility, but by the utility of the last water unit consumed.

Fig.1.1 Relation between marginal utility and quantity of water and diamonds consumed



The above text implies that according to neoclassical theory the price of goods is determined by the ratio of demand and supply. If the goods is abundant relative to the demand, then it is supplied either freely (free goods with zero production costs) or with a price reflecting the production costs (if the goods has to be produced or accommodated for consumption). If a demand for goods is higher than the supply, then its price starts to reflect scarcity. The scarcer the goods become, the higher is the share of scarcity in its price.

From the mode of price setting it is clear that neoclassical theory introduced a new methodology into economics – marginal analysis, i.e. the study of relations among small (incremental) changes. The original interest of classical political economy in a long-term development and the historically conditional view on reality were abandoned while the schematic problems of static equilibrium were put in the forefront – a market equilibrium among the demand and supply of resources and products.

Without the use of the utilitarian social welfare function, **W. Pareto** (1897) developed the criterion of economic efficiency as a state in which it is not possible to make anyone better off without making at least one other person worse off. The Pareto criterion of efficiency carries no ethical content, because it does not take into account the distribution of income and wealth. That is why an efficient allocation need not be necessarily an optimal one (see 1.3 for more details).

On the basis of the libertarian individualism paradigm – individuals that follow their own self-interest by means of unregulated free markets – neoclassical economics became the theory of belief in free markets as the best system for the organisation of social production. According to neoclassical theory, the majority of prices and allocative decisions is to be generated on individual markets among producers and consumers. On these markets, it is determined **what** will be produced, **how** and **for whom** it will be produced.

The answers to these three basic economic questions is given by the market mechanism via final consumers' monetary options – via the willingness and ability of consumers to pay for selected goods and services. From consumer markets, i.e. the markets with final production, markets of production factors are derived – land market, labour market and capital market. On these markets, production factors are given prices – **rents, wages and interests** - that depend on the marginal products of these production factors.

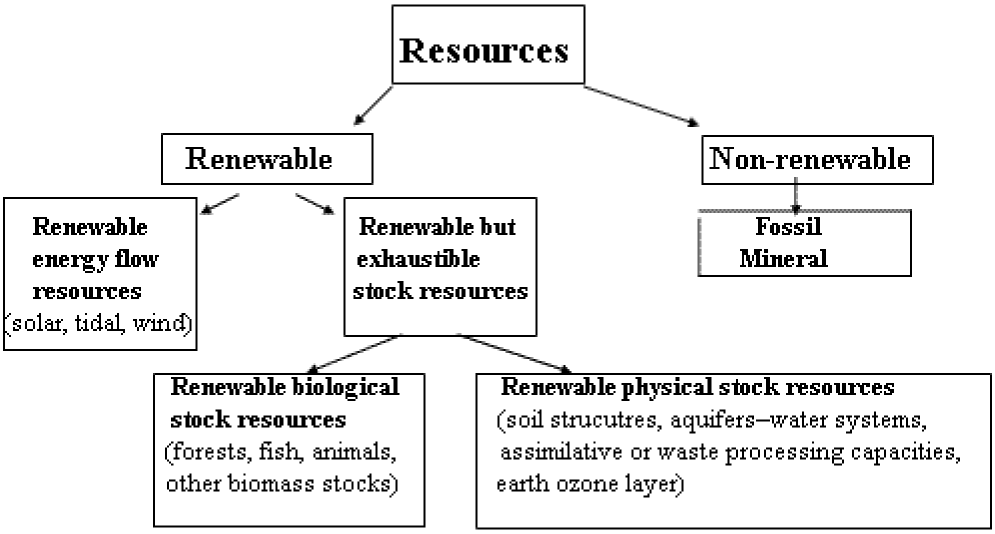
In the economic theory of market economies, rent (net price or royalty) has its robust place and, having a dimension of flow (dependent on time), it expresses the price of land services (in the concept of land meaning, all other natural resources that are fixed in supply as well). For example, an annual rent or annual rent effect reflects the net effect (as the difference between the benefits and costs necessary for the realization of a service) that a land brings during one year. The concept of rent includes also the payment for the use of a natural resource (or for the use of various property). In connection with natural resource pricing, it is more convenient to talk about rent effect that is the basis for such pricing.

In this respect it can be useful to emphasize the difference between the markets of final products and the markets of production factors. When we buy final products, we buy them to satisfy our needs and the needs of our family. On the other hand, when we buy production factors, we buy them for their useful services that they can give us in the production process. For example, if we hire a piece of agricultural land for one year, we hire the services that this plot can bring us during the year. For this plot lease we pay a rent that is derived from the services of the land. It is similar to hiring labour or any other production factor. At the same time, it is necessary to differentiate the lease of production factors – for their finite services we pay rent, wage or interest – from the purchase of production factors. We can buy a piece of land into our personal possession; in this case we buy its infinite future services. Labour forces can be hired, they only existed as an object of purchase in slavery states.

If we take into account the difference between land and other production factors, we must stress that land is fixed in supply. This scarcity flows from the fact that land is the earth surface which is clearly limited. The linkage of the notion land with earth surface is explicit in juridical dictionary in the words „immovable" or „dead stock" (alternative notions: estate, real estate, real property, realty).

According to economic theory, land and other natural resources are the nonextensive production factors. They cannot be enlarged according to the needs, wants and wishes of humans. In many current textbooks, natural resources are divided into renewable natural resources (agricultural land, forests, water resources) and non-renewable natural resources (mineral deposits). Another structuring is into exhaustible and non-exhaustible natural resources. One such classification is in the following chart:

A classification of natural and environmental resources



At the end of this theoretical part devoted to neoclassical economics it must be stressed that it would not be true to say that neoclassicists fully ignored ecological questions. The problem of externalities was introduced by A. Marshall in 1890 and at the beginning of the 20th century the idea was elaborated by A. Pigou (1920). Nevertheless, it is proper to say that up to the mid-20th century, neoclassical economists treated externalities and environmental pollution as an exceptional economic problem.

1.3. Welfare economics and the environment

In the link with utilitarian philosophy in neoclassical economics during the 20th century, a new direction was developed, called the theory of welfare. It attempts to provide the framework for efficient and optimal allocations of resources, including natural resources.

One of the basic axioms of today's environmental economics is the assertion that natural resources are scarce. Scarcity means that resources are limited in the sense that the demand is higher than their supply and that it is necessary to decide on their rational, i.e. effective use. Resources should be used effectively and in an optimal way. Thus, the main interest of welfare theory is the effective and optimal use of resources.

Let us start with the simplest case of a static allocation of production factors. We can use the Pareto efficiency principle (named after the Italian economist W. Pareto) which states that an allocation is efficient in cases where the welfare of any person cannot be increased without making at least one other person worse off. Contrary, an allocation is inefficient if it is possible to increase the welfare of an individual without reducing the welfare of another (Perman, Ma, McGilvray, 1996).

To illustrate the static economic efficiency (abstracted from time), let us consider a simple economy of two persons A and B, two products *X* and *Y* and two production factors K and L. These productive inputs are available in fixed quantities. We also suppose that there are no externalities and both goods are private goods (there are no public goods). The utility of a society can be put as the utility of both persons A and B

$$U_A = U_A\ (X_A, Y_A)$$

$$U_B = U_B\ (X_B, Y_B) \qquad (1)$$

Where utility enjoyed by person A depends upon the quantities he or she consumes of goods X and goods Y and similarly for person B.

Production function for goods X and goods Y can be written as

$$X = X\ (K_X, L_X)$$

$$Y = Y\ (K_Y, L_Y) \qquad (2)$$

If the marginal utility that A derives from the consumption of goods X is denoted as $U_X^A = \partial U^A/\partial X^A$ and the marginal product of the input L in the production of goods Y is $MP_L^Y = \partial Y / \partial L^Y$ and if equivalent notations apply for the three other marginal utilities and the three other marginal products, we can then introduce three conditions that must be met if resources are to be allocated efficiently.

Consumption efficiency requires that the ratios of the marginal utilities of goods X and Y are the same for each consumer. That is

$$\left(\frac{U_X}{U_Y}\right)_A = \left(\frac{U_X}{U_Y}\right)_B \qquad (3)$$

If this condition is not met, then the two consumers can exchange commodities at the margin in such a way that both gain and neither suffers. For example, suppose that the ratios of marginal utilities were as follows,

$$\left(\frac{6}{3}\right)_A = \left(\frac{2}{4}\right)_B \qquad (4)$$

i.e., if consumer A values X twice as highly as Y, while consumer B values X at only half the value of Y, then if A exchanged one unit of Y for one unit of X from consumer B, both would gain.

Production is effective when the ratio of the marginal product of each input is identical in the production of both goods, i.e. when it is not possible to increase efficiency by exchanging production factors among producers.

$$\left(\frac{MP_L}{MP_K}\right)_X = \left(\frac{MP_L}{MP_K}\right)_Y \qquad (5)$$

The final condition which is necessary for economic efficiency is the “product-mix efficiency” which requires that

$$\left(\frac{U_X}{U_Y}\right) = \left(\frac{MP_K^Y}{MP_K^X}\right) \tag{6}$$

Equation (5) can be rearranged to yield the following relation that shows that ratios of marginal products of capital and labour are equal

$$\left(\frac{MP_K^Y}{MP_K^X}\right) = \left(\frac{MP_L^Y}{MP_L^X}\right) \tag{7}$$

This equation implies that the ratio of marginal utilities of both products must be equal to the ratio of marginal products of labour and capital.

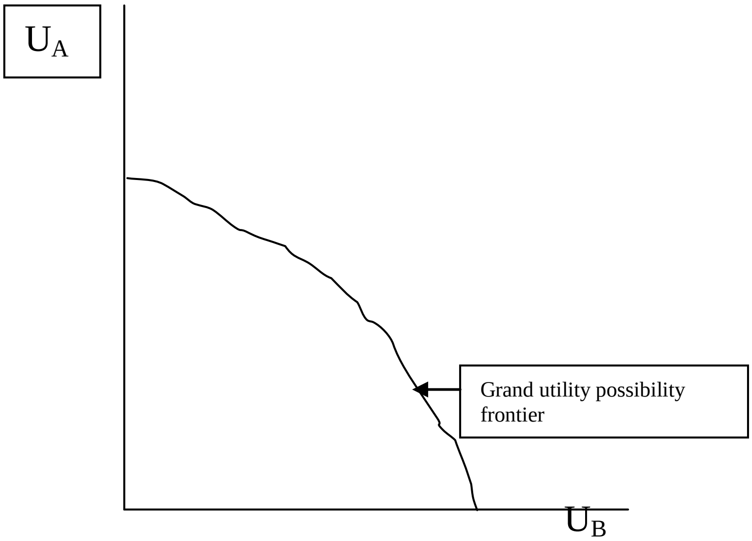
$$\left(\frac{U_X}{U_Y}\right) = \left(\frac{MP_K^Y}{MP_K^X}\right) = \left(\frac{MP_L^Y}{MP_L^X}\right) \tag{8}$$

A simultaneous satisfaction of the conditions (3), (5) and (8) is an assumption for a fully efficient static allocation of resources. These results generalise to economies with many inputs, goods and individuals with the condition that the three efficiency equations have to hold for each possible pairwise comparison that one could make.

The non-uniqueness of efficient allocations

The above mentioned conditions of effective allocation of resources are primarily determined by one particular initial distribution of property rights. If the initial distribution of property rights is different, a different efficient allocation will result. In other words, efficiency carries no ethical content and gives no criterion to say which allocation is best from the social point of view.

If we restrict our attention to the two person special case again, we can represent this idea using the concept of *Grand Utility Possibility Frontier*, illustrated in the next figure. Each point on this frontier is an efficient allocation of resources satisfying the three necessary conditions, the position an economy takes on this frontier depends upon the intitial distribution of property rights. There is clearly an infinite number of efficient allocations.



To discuss the well-being or welfare of a society requires that some ethical criterion be adopted, for example in the form of a social welfare function (SWF) that can in general form be written as:

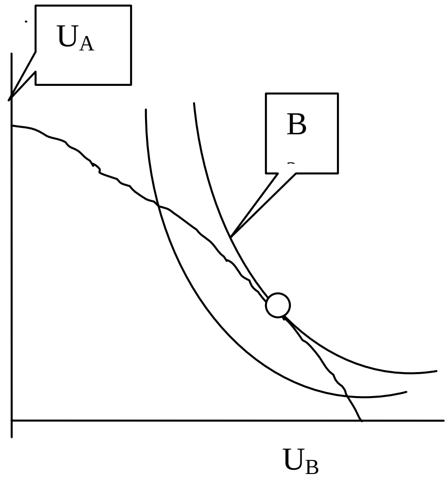
$$W = W\,(U_A,\, U_B) \qquad (9)$$

SWF gives a criterion that enables interpersonal comparisons to be made. If we have SWF (that is non-declining), we can logically suppose that under optimal allocation of resources, the SWF is at its highest level. If the convex curves are social welfare indifference curves (each one is contructed to represent combinations of individual utilities that yield a costant level of social welfare), then the SWF maximum is attained at the level of welfare B_2 in point of contact of indifference curve with utility possibility frontier (point is marked by circle). In the tangent point, the slopes of both curves are the same (it is the only one optimal point, because in all other points the slopes are not identical).

It means that a static efficiency of resource allocation is achieved if the conditions (3), (5) and (8) are simultaneously met and the maximised welfare implies an additional necessary condition

$$\left(\frac{U_X^B}{U_Y^A}\right) = \left(\frac{W_{U_A}}{W_{U_B}}\right) \qquad (10)$$

The left-hand side of this equation is the slope of the utility possibility frontier; the righ-hand side term is the slope of the social welfare indifference curve (B2). At the social welfare maximum (circle), these slopes must be equal.



An allocation of resources over time is intertemporally efficient if for some given level of utility at the present time, utility at all future points in time is as high as is economically feasible. In other words, utility can only be increased at the expense of current utility.

An effective allocation of resources can be achieved in different institutional conditions, like in dictatorship, centrally planned economy or free markets. Each of them can, but will not necessarily, achieve an effective allocation of resources.

The institutional arrangements necessary for an efficient static allocation of resources in free market economy include the following (Perman, Ma, McGilvray, 1996, p. 90):
1) markets exist for all goods and services exchanged,
2) all markets are perfectly competitive,
3) all transactions have perfect information,
4) property rights are fully assigned,
5) no externalities exist,
6) all goods and services are private goods, there are no public goods and no common property resources,
7) long-run average costs are non-decreasing (if production were characterised by economies of scale, then natural monopolies would exist, and a competitive conditions could not be sustained).

An efficient static and intertemporal allocation would be sustained if these seven institutional circumstances, in all points in time now and in future, were satisfied.

1.4. Environment, ethics and discounting the future

Environmental and natural resource economics deal with allocation, distribution and use of natural and environmental resources. These problems can be seen from the viewpoint of positive economics, which does not require the adoption of any particular ethical viewpoint. It treats only the causes and consequences under given assumptions. Many economists take this approach as insufficient, because economics as a social science on the relations among people in the processes of production, exchange and consumption, and environmental economics as a science on the relations among economic systems and environment cannot abstract from these relations and should answer the questions of what to produce and what policy is the best one. This means that many economists wish to address the questions of what should be done in a particular set of circumstances, or what is the best policy in a given context.

In the not-so-long history of economic theory, most economists have tended to employ some variety of utilitarian moral philosophy [**David Hume** (1711-1776), **Jeremy Bentham** (1748-1832), **J.S. Mill** (1806-1873)] and it can be said that mainstream environmental and resource economics in market economies comes primarily from the utilitarian ethical position. Utilitarianism is a consequentialist philosophy; the moral worth of an action is determined solely by the consequences or outcomes of an action for the valuing subject. Classical utilitarians supposed that social well-being is cardinally measurable (by some common units of utility, like the so called util) in time and space in some form of aggregation of the utilities of all relevant persons. One thing that is agreed by all utilitarians is that social good is some form of aggregation of all relevant persons.

Modern neoclassical utilitarians do not make use of the assumption that utility is cardinally measurable. But within this more general approach, modern utilitarianism is unable in itself to compare and rank the welfare outcomes corresponding to different initial allocations of wealth to different individuals. The price paid for not assuming that utility is cardinal and comparable between individuals is the inability to decide whether one distribution of wealth is better than another. The common assumption in cost-benefit analyses then is that the marginal utility of consumption is equal for all individuals. If marginal utilities are not equal (which is very realistic) then we have to respect the fact that the original distribution of wealth is decisive for any considerations about relations between individual and social utility.

Neoclassical utilitarianism is criticised from many aspects. **A. Sen** (1987) shows that the welfare of individual is a function of something much broader than the utility enjoyed through consumption, including personal rights, freedom and liberty as a part of the intrinsic values of individuals. Moreover, for many individuals values are not given only by personal welfare. All persons have fundamental dualism, being concerned with their well-being but also being agents with objectives which they would like to see obtained. The value systems of individuals is broader than only their self-interest, than the utility enjoyed through their consumption (they may ascribe positive values to other living species, they may wish poverty to be eliminated etc.).

What are then the main objections against neoclassical individualistic paradigm and against market systems based on this paradigm?

1) Neoclassical economics takes society as a sum of self-interested individuals and it has never considered economics as a social science. By defining human behaviour in utilitarian terms, this theory represents purely materialistic interpretation of human existence. At the same time it has eliminated the political and ethical dimensions of man, leaving the economic sphere entirely autonomous.

2) Neoclassical economics consider the environment as external to the market. Originally, the term “externality” (an idea formulated by A. Marshall and later mainly by A. C. Pigou, 1920) was treated as something exceptional and extraordinary. Only currently the fact that running the economy permanently requires resources which are

permanently returned back as waste and change subsequently the quality of environment starts to be respected.

3) Liberal market systems are vital only in conditions of economic growth, i.e. in the conditions of permanent enlarging production and consumption per head, invested capital, area unit etc. The success of these economies is based on mass consumption and the higher the consumption, the better the market system results. This is, of course, in direct contradiction with sustainability and with frugal use of natural resources.

4) Economic systems based on a self-interested behaviour of individuals improve social welfare but not always as effectively as the systems based on some forms of cooperation. The "Prisoner's Dilemma" proved already in 1950 that the rational behaviour of an individual leads to an apparently irrational social outcomes, if the behaviour of individuals is mutually dependent (and in economic activities interdependency is a general characteristic).

5) Self-regulating markets fail to satisfy the basic human deficiency needs, because they have a built-in tendency to undervalue needs and overvalue wants (desires). As the elementary human needs have the price and income elasticity of demand usually lower than 1, the supply is artificially diminished by producers and distributors (who in contemporary market structures usually have the economic power to do that), because a higher price increases their total revenue. It means that contemporary markets (for which perfect competition is only an illusion) are not a perfect allocator, but fail from their own substance, because they overprice the necessities and underprice the luxuries. The main problem of a market as an allocator is that it stimulates the consumption of luxuries mainly, which is again in contradiction with sustainable development.

6) The inadequacies of macroeconomic **national accounting** (GNP - gross national product, GDP - gross domestic product, NNP - net national product, NDP - net domestic product; gross social product and national income in Marxist national accounting) as a measure of social welfare have been remembered for a long time by local and global environmental degradations. In fact, the belief in a never-ending exponential economic growth (the growth of production and consumption of goods and services), as measured in national accounts, is the heart of environmental problems.
National accounts are usually explained as a measure of social welfare (satisfaction of wants) and essentially they are short-term measures of total economic activity on markets in monetary terms. In reality the concept of welfare is much more broader than the monetary measure of income and covers many dimensions of subjective well-being, connected with social, ecological and ethical dimensions of human life. In relation to the natural environment, the current system of national accounts is especially criticised for the following main shortcomings:

- depletion and degradation of natural and environmental resources are not recorded (national income as a flow of marketed goods and services does not include the changes in natural resource stocks)
- it disregards the environmental damage caused by production and consumption
- current expenditures of public sector and households for environmental protection are included in the final demand and, thus, increase the national income, but many economists argue that these defensive expenditures should be viewed as inputs and thus deducted from national income.

It has been said that neoclassical economics is not a social science, it is a science of self-interested (rational) individual. Society is taken merely as a sum of individuals. The optimization of economic welfare is the result of individual strategies.

On the other hand, it has been well-known for centuries that a joint effort of two individuals can give better results than when they act individually. But this very trivial fact, which have accompanied the human society throughout its history, is not respected by neoclassical economics. This theory treats any couple simply as two individuals acting individually in accordance with their own separate self-interests (neoclassical approach to the family see Becker, 1981). This is the reason why any society based on the neoclassical paradigm is "condemned to a prison of self-interest". This is the reflection of a strong criticism of self-interest, which was presented in 1950 in the so-called "Prisoner's Dilemma", written by three American scholars (Flood, Dresher, Tucker) and applicable to the whole neoclassical paradigm.

On the base of the prisoner's dilemma it can be illustrated - in a direct refutation of Smith's invisible hand - that the self-interested maximization of utility by individuals leads to a non-optimal societal performance. If a private owner seeks to maximize profit, he minimizes employee wages. Yet if labourers defend their entitled wages and rights through trade unions, a non-cooperative environment emerges. The only way to overcome non-cooperation is to substitute the self-interested system by the system stimulating cooperative behaviour.

The experience of recent decades proves that countries with prevailing non-cooperative economies (the leading example are the United States) have comparatively lower economic performance than countries that incorporate means of cooperation among labour management and owners (the leading example is Japan). Both dangers and failures of separating the private owners and labourers have been fully recognized in the Japanese economy. In their model, worker welfare is a concern along with the bottom line of the profit sheet. The businesses are not controlled by shareholders, but by their workers, with managers being drawn from leading workers. Also, rather than cutting workers to maintain dividends, the Japanese advocate cutting the dividends; they also enforce a ceiling on the salaries of managers, limiting them at five times the salary of a worker. Japan's leading economic position in the world proves that the Japanese way of cooperative behaviour is the true challenge for overcoming the inequalities of the standard market economy (Seják, 1999).

It has also been mentioned that self-regulating markets undervalue the needs and overvalue the wants. The contemporary market systems constantly "produce" new sorts of wants, most of which are false wants, i.e. the wants without which people can live. The paradigm of liberal market systems identifies success and happiness with the level of consumption and with the ownership of things. The natural desire of people for better living has obtained the perverse form of higher consumption. The question is whether it is possible to change the market economy to start satisfying only true human needs and whether such change would not deny the market system alone.

The problem of the true and false (right and wrong) needs is very old and its explanation in various economic theories differs. It was neoclassical economics which erased the difference between true and false needs and started to respect only the wants as such, more specifically the demand. It is connected with the role of the market, which is ready to satisfy every payable want, no matter whether these wants are true or false, whether they are harmful for the consumer (drugs etc.) or harmful for others (smoking, individual car transportation etc.). The market evaluates the wants only by the willingness or ability to pay and not by the fact as to whether or not these are true needs (physiological, cultural, social etc.) or other wants (harmful, unnecessary).

The failure of a market as an allocator consists not only in the fact that it does not distinguish true and false wants, but especially in the fact that it has an in-built tendency to undervalue (suppress, constrain) the true needs and overvalue (prefer) the false wants. For example, nearly all contemporary systems of commercial advertisement support mainly the unnecessary wants. As the right human needs are limited in their extent (food, clothes, shelter, education, social respect and usefulness etc.), the growth of market economies means mainly extending false wants.

From this point of view, humanistic economics stresses that market fails as a mechanism of a socially-needed allocation. The failure of the market generates permanent social tensions as a result of unjustified distribution not only within individual economies, but also on the global scale, notably in the North-South economic relations.

In spite of these facts, neoclassical economics continues to stress that the unregulated market is a perfect allocator and that, if left free, it leads to optimal social results. The contemporary world awaits the answer to the question of what correction of the market system is necessary for the realization of minimum requests of sustainability.

Recently, such request has been put forward as a conclusion of the 1993 report by the World Watch Institute: “Mankind should develop the economic system which would sustain environment.” (State of the World 1993, World Watch Institute, Washington, D.C.)

In economic theory it has been known for a long time that the very specific conditions of perfect competition are characterized by the following institutional arrangements (Perman, Ma, McGilvray, 1996, p. 93):

1) markets exist for all goods and services,

2) all markets are perfectly competitive,

3) no externalities exist,

4) all goods and services are private goods, there are no public goods,

5) property rights are fully assigned,

6) all transactions have perfect information,

7) all firms are profit maximisers and all individuals utility maximisers,

8) long-run average costs are non-decreasing,

9) transactions costs are zero,

10) all relevant functions satisfy convexity conditions.

It is generally well-known among economists that the above mentioned conditions for effective resource allocation are not met in the current market economies. This means that practically in all market economies there are externalities and public goods, there is no perfect information and there is such high concentration of productions that many producers and distributors have power to dictate the prices. In all these cases markets fail.

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Chapter 2. Natural resource economics

Since the beginning of the industrial revolution, utilitarian philosophy has perceived natural resources as the flows of services (flows of benefits and costs) which these resources can bring in some time horizons. For the valuation of natural resources as a sum of expected future benefits (gains) from their usage, a decisive role is played, beside the magnitude of the above mentioned gains, by the so called time factor which expresses the rate of unequality of benefits and costs in time. Let us note that in the following text the concept of price will be taken as synonymous with the value concept, i.e. it will be understood as a common or standard market price.

2.1. Time Factor (discounting)

An economic analysis in market economies expresses the fact that people value present economic magnitudes (today's benefits and costs) higher than the same magnitudes in future (future benefits and costs). One Euro today is valued more than one Euro next year; people have positive time preference ("*One Euro today is worth more to me than one Euro next year."*). Such intertemporal decrease of value is known as discounting (discounting is any process of revaluing a future event, condition, service or product to give a present equivalent – present value). The process of discounting is known not only from financial markets (where it is known as a part of "financial aritmetics"), but practically in all economic activities.

Discounting in market economies is a standard part of cost-benefit analysis, i.e. it is a standard part of economic efficiency. Discounting implies that the future has less importance than the present. In all such cases it is necessary to quantify how much better it is to have a good thing now in comparison with its future disposal.

In order to compare some good things or some amounts in time, we use the concept of ***present value***, which is used to give an equivalent of a future value at present (t=0). Let it be considered "10 % better" to have the thing (or amount) now rather than in a year's time:

[a good thing now] is equivalent to [a good thing in a year] + 10 % x [a good thing in a year]

The process of discounting can be expressed in a simple mathematical form:

Present value of some future benefit, revenue or cost = imputed future value x discount factor

where discount factor (time factor) is invariably presumed to be less than one, and for one year time period specifically it is *1/1+i*, where *i* is annual discount rate in hundredths (in percentages). If *i* is a positive number, then the discount factor is evidently less than one. The discount factor shows the present value of a monetary unit that will be gained in one year's time.

If €1 is worth €1$(1+i)^5$ in five years time at a rate of interest of i per cent, then €1 in five years time must be worth €1/$(1+i)^5$ now. This is ***the present value*** of €1 in five years time. More generally, the present value of €1 in year t is: €1/$(1+i)^t$.

Discounting for a number of time periods can be commonly expressed in the general form:

$$K_o = K_t / (1+i)^t$$

where K_o = present value of a benefit, cost or revenue K_t, expected t years after some reference date,
K_t = is a benefit, cost or revenue expected t years after some reference date,
i = is the discount rate in hundredths (in percentages),
$1/(1+i)^t$ = discount factor for t periods.

Having the present value in cash at the reference date (when t is 0) is just as good as having the cash value of K_t in t years time.

The process of discounting can best be understood by looking at the mechanism of compound interest (capitalization). While under simple interest running, the net revenue in the form of interest at the end of every year is withdrawn from the bank and at the beginning of any year the amount capitalized is the same, under compound interest running, the revenues from the interest are added to the original amount, i.e. in any new period the amount capitalized is growing.

If we invest for example €100 now, then at 5% interest rate annually we will have an amount of €115,76 after three years.

100 105 110,25 115,76

1st year 2nd year 3rd year

At the end of the first year we will have an amount of €100 + (100 x 0.05) = 105, at the end of the second year then €100 + (100 x 0.05) + (100 + 100 x 0.05) x 0.05 = 110.25, at the end of the third year we will have the amount from the end of the second year plus the same amount multiplied by interest rate, it means

100 + (100 x 0.05) + (100 + 100 x 0.05) x 0,05 + /100 + (100 x 0.05) + (100 + 100 x 0.05) x 0.05/ x 0.05 = €115.76.

This seemingly complicated process can be expressed in a much more simple form. If we indicate the original investment K_o and the interest rate as i, then the total amount at the end of the first year is $K_o + K_o i$. That can be written as $K_o(1+i)$, which will be supplemented at the end of the second year by $K_o(1+i)i$. It means that at the end of the second year the total amount will be $K_o(1+i) + K_o(1+i)i$, i.e. $K_o(1+i)(1+i)$, which can be written as $K_o(1+i)^2$. Similarly, the total amount at the end of the third year will be $K_o(1+i)^3$. This generalized formula for compound interest running (capitalization) can be written, for the initial amount K_o, discount rate i and number of periods n, as

$$K_n = K_o (1+i)^n \qquad (1)$$

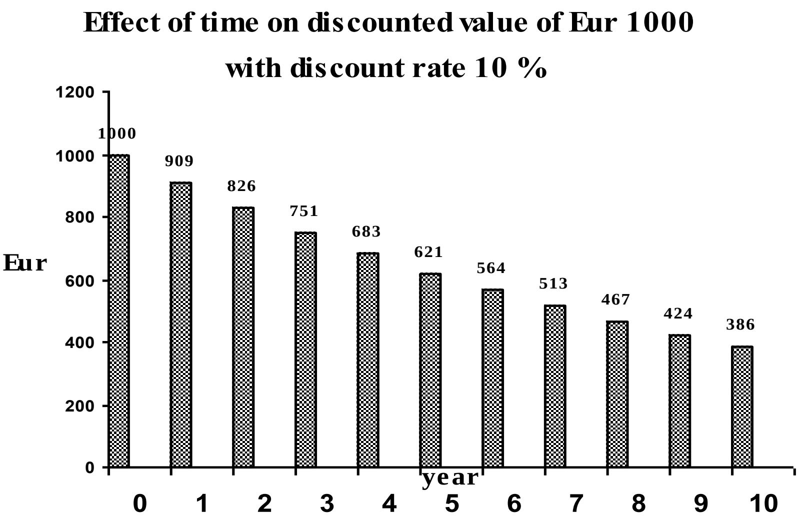
Discounting is the reverse of capitalization, discounting is really only compound interest back-to-front.

$$K_o = \frac{K_n}{(1+i)^n} = K_n \quad 1 / (1+i)^n \qquad (2)$$

where K_o is a present value of K_n, which we will have in period n. The discount factor $1 / (1+i)^n$ expresses the present value of one Euro that can be obtained after n years with the discount rate i.

For example, in case we will have €1,000 in one year period, then under a 10% interest rate the present value is €909.0909. In other words, if we invest an amount of €909.10 with a 10% interest rate, in one year period we will have an amount of €1,000. The effect of discounting on the future value of €1,000 in the period of 10 years under a 10% discount rate is showed in the next chart. The present value of one thousand Euro in one year (t = 1) is €909 (exactly €909.09), the present value of one thousand Euro in a ten years period is only €386 (see chart 2.1).

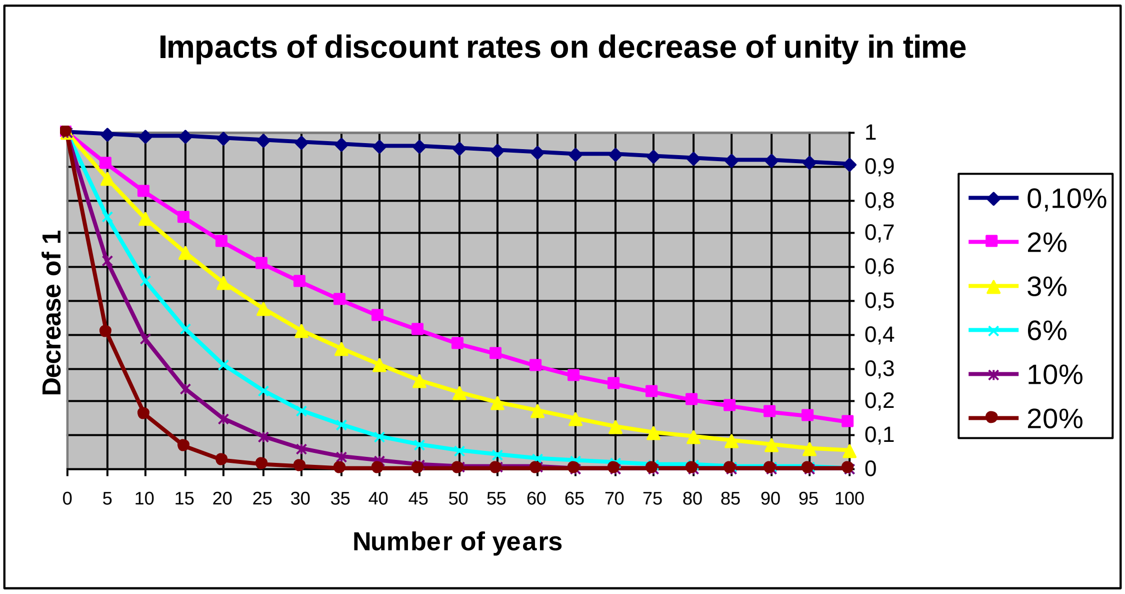
Chart 2.1



As we can see, with the 10% discount rate only around one third is left from €1000 in ten years (exactly €385.54). We test this by depositing the amount of €385.54 with the 10% interest rate; according to the formula (1), $1000 = 385.54 \bullet (1.1)^{10}$. The present value of €1000 that we will have in ten years is only €385.54. Having the present value in cash at the reference date (when t=0) is just as good as having the cash value of X_t in t years time.

A graph of $1/(1+i)^t$ against time is shown as a solid line in figure 2.2. This reveals the powerful effect of discounting on value, the more so the longer the period and the higher the discount rate. The discount factor declines more or less rapidly towards zero, but it never actually reaches it (see chart 2.2.).

Chart 2.2



From both charts it is clear that discounting has a powerful effect on value reduction in time. With a discount rate of 20 %, 1000 is reduced in twenty years to only about Euro 26. In other words, the present value of €1000 that we will have in twenty years, with the discount rate of 20 %, is only €26. With high discount rates, the time horizon for decision-making is necessarily very short. The time horizon is inversely proportional to the discount rate level.

From chart 2.1. we can see that with a discount rate of 10 %, the original amount loses around one half after seven years; from chart 2.2. we can similarly see that with a 10 % discount rate it has no sense to take into account a time horizon that is longer than 15 or 20 years (in twenty years the original amount loses around 85 % of the value). With lower discount rates, the rate of depreciation or devaluation retards. Chart 2.2. shows that under a 2 % discount rate, we still have around 40 % of the original amount after 50 years (in other words, the present value of €1 after 50 years is around 40 cents). Sustainability principles request to take into account the long-term impacts of human activities, like impacts of global climate change on future generations. This is reflected by the use of a very low discount rate. Chart 2.2. shows that under a 0.1% discount rate, we have around 90 % of the original amount after 100 years (used in Stern review, 2006).

Why do positive discount and interest rates exist and arise? There are two substantial reasons. First, individuals attach less weight to a benefit or cost in the future than they do to a benefit or cost now, people discount future as they prefer to have benefits now rather than later and costs later rather than now, they prefer present gains against future ones. This expresses what we call impatience or time preference. Human individuals are impatient. If we accept an assumption that human preferences are relevant, we must also accept that people prefer nowadays to future.

Second, as another reason for a positive discount rate is the productivity of capital, €1 worth of resources now will generate more than a €1 worth of goods and resources in the future. Hence an entrepreneur would be willing to pay more than €1 in the future to acquire €1 worth of these resources now. Presently available money can gain interest or dividends; presently owned resources can be used to form profit-yielding investments; presently possessed land offers immediate rental value. The basic fact is that if we invest some money instead of spending them for consumption, we expect that the investment will bring us a higher consumption in the future period. We will make such investment if we expect that its future benefits will be higher than the costs of impatience (rate of time preference). This argument for discounting is referred to as the “marginal productivity of capital” argument, the use of the word “marginal” indicating that it is the productivity of additional units of capital that is relevant.

There is a clear independency among both the reasons of positive discount and interest rates. For the process of investing, it should be valid that the “marginal productivity of capital” should be higher than the “marginal time preference”, in other words, a process of investing can continue up to the moment when the benefit from marginal unit of investment is not lower than the marginal time preference.

Inflation is very often quoted as the reason for discounting. It is clear that inflation - a general increase in the prices of goods, services and resources – is pervasive. The relations between inflation and discounting are extensively discussed in economic literature and the conclusions of individual authors are far from being uniform. Undoubtedly, inflation must be taken into account in discounting and over time. Generally, it may be said that inflation, in the evaluation of future, need not be a great problem, provided that inflation is expected and flexible exchange rates are enforced. At the same time, it is obvious that nominal discount rate should be higher than the rate of inflation, because in the opposite case there would be a decrease of real values over time.
Note that the relationship of interest rates and inflation is not precisely additive. If money interest is to compensate fully for inflation, the appropriate rate is given by $i_n = (1+i_r)\bullet(1+I)-1$. This precise formulation is not always recognized in literature, and the difference from the approximate form

money interest rate i_n = real interest rate i_r + inflation rate I

can become important in high-inflation economies.

In discounting, it is thus necessary to carefully differentiate among nominal (money interest rate) and real discount rate. A nominal discount rate expresses the total rate including inflation, while a real rate means the net discount rate after a subtraction of inflation. The relations can be put followingly:

$$i_n = (1+i_r)\bullet(1+I)-1$$

where i_n = nominal discount rate, i_r = real discount rate, I = rate of inflation. With a negligible error, nominal rate can be written as a sum of real discount rate and rate of inflation.

Discounting generally implies that the future has less importance than the present. Discounting was introduced in market economies only in the last two centuries. It is possible to say that discounting contributed to the unsustainability of current market economies. If discounting is applied on the activities of a long-term character, like education, scientific research etc., but also on the economic activities of a long-term character (like forest management and generally ecological functions of nature), it leads to preferring only the short-term measurements and it practically hinders the possibilities of long-term actions.

If in natural resource extraction the capital is allocated on the actions that are profitable under discounting, then it leads to the preference of short-term investments and it threatens the existence of freely accessible natural resources. It is typical for fishery in international waters, where the efforts of the capital to obtain immediate profit reduced many fish species near extinction or even destroyed them.

Ecologist Paul Ehrlich once asked a Japanese journalist why the Japanese whaling industry is busily exterminating the very source of its wealth. The answer: "*You are thinking of the whaling industry as an organization interested in maintaining whales. Actually it is better viewed as a huge quantity of capital attempting to earn the highest possible return. If it can exterminate whales in ten years and make 15 percent profit, but it could only make 10 percent with a sustainable harvest, then it will exterminate them in ten years. After that, the money will be moved to exterminate some other resource.*" (Meadows D., 1990)

It is thus necessary for any democratic system to prevent the long-term interest of citizens, i.e. to protect also the quality of the environment. A. C. Pigou introduced this request in 1929 in the following way: "*There is wide agreement that the State should protect the interests of the future in some degree against the effects of our irrational discounting..."* (Pigou, 1929, p. 29)

For example, at one time the British Forestry Commission was using 10 % as a discount rate for the decisions on crop harvesting method, 7.5 % for the decisions on commercial recreation, 5 % for the decisions on silvicultural practice, 3 % for the decisions on land acquision, and as low as 1 % when forestry activity had a social justification (Price, 1993, p. 118).

The protection of future interests was also the reason why in former Czechoslovakia the state determined a 2% discount rate in forestry as the highest permissible rate.

It must be said that the problem of discounting and selection of discount rates is not an entirely clear area in economic theory. The question whether the rate of discount is proper or not can be answered only depending on the purpose of intertemporal comparisons. If the aim is an evaluation of economic efficiency (whose part is an evaluation of cost and benefits of natural resources), then the use of a positive discount rate is correct. Conventional discounting is correct in private investments where the self-interest from alternative investment strategies is estimated. Any such individual uses a discount rate level according to his/her individual conditions and expectations.

As a convenient level of discount rate it is possible to take for example the rate of return from the best opportunity lost. From the investor's viewpoint, for those who want to buy some land or other natural resources, opportunity lost is the interest rate that could be gained if the investment was allocated into a bank. Generally, as the bottom limit for the discount rate, a discount rate of the central bank can be used for which money are lent to commercial banks.

In public projects, costs and benefits should be discounted by public discount rates that are generally lower in comparison with private rates (they do not contain private risks).

The use of discounting implicitly assumes that all benefits are fully reinvested. This is a difficult assumption that does not take place in many practical cases. Discounting is then improper. Discounting also comes from the assumption that the future value of some evaluated resource will be decreasing, that its marginal utility will decrease; it means that its volume will increase. Some products or resources can keep the same quality or even improve it over time. The discount rates should then be zero or even negative. Generally, negative rates of discount produce nonlogical results in economics because discounted magnitudes grow with time.

Many environmental economists seem to argue that the only ethically defensible discount rate for the projects whose effects spread over several generations is zero. It means that in many cases it can be proper to evaluate itertemporal magnitudes under a zero discount rate.

In the next two parts, we show how the time factor influences the economic efficiency of human activities and the values of natural resources.

2.2. Cost-benefit Analysis

Everyone is used to taking decisions on the basis of a balance of gains (benefits) and losses (costs), advantages and disadvantages in choosing the greatest net gain. Such comparison in economics is called cost-benefit analysis (CBA).

The basic cost-benefit rule is very simple and it means that a project, policy or programme is effective if the total benefits are higher than the total costs. The difference between benefits and costs is called net value. The flows of costs and benefits over time are discounted and the result is expressed as a net present value number, or as a discounted benefit-cost ratio. A positive net present value and the ratio of benefits and costs >1 express an economically effective project, policy or programme.

CBA distinguishes among the costs and benefits of an individual and the social costs and benefits. An individual’s costs and benefits are defined according to the satisfaction of wants, or preferences. If something meets a want, then it is a benefit. If it detracts from wants, it is a cost. An individual should accept a proposal to change to situation A if

$$(B_A - C_A) > 0$$

where *B* is benefit and *C* is cost.

Social costs and benefits can simply be expressed as a sum of costs and benefits of individuals.

The conversion of costs and benefits of different time periods on the present value is done by discounting or by capitalisation, as it was described by (2) a (1) in the preceding part.

The basic formula for computing a net present value (NPV) is

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+i)^t} \qquad (3)$$

The CBA rule then is that for any policy or project, the NPV should be positive.

To illustrate the above rule, consider a project that has the following sequence of costs and benefits:

	year 0	year 1	year 2	year 3	year 4
cost	30	10	0	0	0
benefit	0	5	15	15	15
net benefit	-30	-5	15	15	15

Note that the costs appear as minuses and the benefits as pluses. Year 0 expresses the present period, in which the valuation is done.

Suppose the discount rate is 10 % (which is written as 0.1), the NPV is:

$$\frac{-30}{1} + \frac{-5}{1.1} + \frac{15}{(1.1)^2} + \frac{15}{(1.1)^3} + \frac{15}{(1.1)^4} = -30 - 4{,}5 + 12{,}4 + 11{,}3 + 10{,}2 = -0{,}6$$

The NPV is negative and therefore the project is not worthwhile. Note that without the discounting procedure, the benefits of 50 exceed the costs of 40. Discounting can therefore make a big difference to the ultimate decision to accept or reject a project.

Let us consider an industrial project that is based on the use of agricultural land and that will lead to the pollution of an ecologically valuable region. An important question here is what society is losing in the form of a changed agricultural land and in the form of polluting an ecologically valuable region. We need to know what the total economic value of the lost nature services is. Such value comprises a use value (tourism, nature viewing, hunting etc.) and an existence value (the local inhabitants and visitors can value naturally a valuable territory independently on the use). In the assessment of the above mentioned project, all forms of use and non-use value of respective nature must be taken into account (details in chapter 4). The project can be valued as economically effective only in case the benefits (economic gains) are higher than the full social costs.

In practice, project evaluation can be even more complicated by the aspect of uncertainty. From the viewpoint of nature conservation, uncertainty exists whether an ecologically valuable territory will be saved. It is not clear whether industrial emissions do not destroy or damage the region. Alternatively, it is necessary to evaluate the prospects for the restoration of the respective region or for the creation of a new ecosystem. Inclusion of uncertainty means an incorporation of option value that expresses some kind of insurance that individuals are willing to pay for future use and access to an environmentally valuable region. The total project cost thus includes the losses from the use, option and existence value caused by the project.

The basic CBA rule for accepting a project is thus the following:

Accept the project if the sum of discounted net benefits is higher than 0

$$\sum (V_t - N_t - E_t)\, 1/(1+i)^t > 0$$

where E_t are the total environmental costs of the project.

Such environmental costs include the total economic value of nature services lost in the form of use, optional and existence value, or the costs necessary for the restoration of such services. These problems are described in detail in chapter 4 that presents an overview of non-market valuation methods.

2.3. Basic methods of natural resource pricing

We can value the marketed natural resource as an asset by one of the three following methods:

1. deriving from the value of a similar resource (comparative method)
2. according to the costs necessary for resource use (cost method)
3. according to the resource net benefits (net yield, net revenue, rate of return/rent method).

The net yield method is the most natural and the most frequently used method in market economies as it values a natural resource by summing the future net yields (rents) through the interval of its use. This interval can be either limited like in the case of mineral deposits where the resource stock is limited, or unlimited (infinite) in the case of renewable natural resources (like agricultural lands, urban lands, forests, water resources). It is not the natural resource that is valued by the net yield method, but only a series of its net services.

In market economies, the value of a natural resource is thus expressed, similarly as in the cases of other production factors, as a value of future net services of these resources that serve for satisfying human needs, i.e. as a sum of the discounted future net benefits over the interval of its use.

The general formula for estimating the natural resource value can be written in the following form

$$V = \sum_t \frac{r_t}{(1+i_t)^t} \tag{4}$$

where V = the current value of an asset, r_t = expected annual return (rent) in year *t*, i_t = expected value of the discount rate in year *t*. Discount rate is usually expressed in percentages and it enters into the formula in hundredths (e.g. discount rate 7 % enters as 0.07).

The commonness of formula (4) is given by the fact that both rent effects and discount rates are certain functions of time (and that is why they are supplemented by coefficient *t*).

Due to the fact that the expected returns are some function of commodity and input prices, yields, taxes, interest rates, credit terms, inflation rates, the potential for disposing of the natural resource for some higher and better use and a long list of other variables, and similarly discount rate is also a function of many variables (time preference for money, risk and inflation etc.), the common formula is simplified by different assumptions. The most frequent assumption of a constant rent benefit *r* over time, as well as a constant discount rate *i* over time, and in the case of renewable natural resources an assumption of infinite time horizon of their use (formally it leads to infinite time series that is convergent; see time series in higher mathematics). With these assumptions, formula (4) can be written in the following simple form

$$V_s = \sum_{t=1}^{\infty} \frac{r}{(1+i)^t} = \frac{r}{i} \tag{5}$$

where V_S = natural resource value under assumptions of constant *r* and *i* and infinite time horizon.

This is the simplest formula for estimating a natural resource value by means of the revenue method. The summation of a discounted infinite time series converges to the ratio *r/i*. It is a well known formula of capitalised rent, which shows the natural resource value V_S as an amount that invested into a bank at the interest rate *i* annually brings an interest *r*. For example, if a natural resource earns annually €1000 and the discount rate is 10 % or 0.1, then the natural resource value is €10,000. This amount, deposited into a bank with a 10 % discount rate, earns annually €1000.

Natural resource value is in fact the sum of its future net rent benefits discounted to the present value by a discount rate. As the rent effects are estimated as net gains (a rent is a difference between the total annual benefits and the total costs, and the costs include also a normal profit for other production factors), then we can say that natural resource value is a net present value of this resource (see (3)) .

An alternative formula must be used in valuing forest land, where the rent benefits are not obtained annually, but only after the rotation period that is the period of one or several human generations.

$$C_L = \sum_{u=1}^{\infty} \frac{r_u}{(1+i)^u} = \frac{r_u}{(1+i)^u - 1} \qquad (6)$$

where *u* = rotation period (e.g. 40 or 100 years) and r_u = constant rent effect at the end of a rotation period. The term $(1+i)^u$ can in more simple form be written as $1.0p^u$, where *p* is discount rate in percentage, so e.g. 5 % can be written as 1.05^u. This notation is commonly used in forest economics (see forest valuation chapter in Seják et al., 1999), although it is mathematically incorrect.

In formula (6) it is supposed that the rent effect comes not annually but at the end of a rotation period (forests maturity age) and we are summing these rental effects in infinite time horizon. Formula (6) is thus based on another assumption, i.e. that the first rental effect will be obtained only after the rotation period. It means that we evaluate forest land as the land without vegetation (without stands), which is very frequently unrealistic as for most of the time of the rotation period forest land is covered by stands. This formula is thus used as a supplement (complement) for valuing forest land, while forest stands are valued separately and these two values are summed (this is the current valuation practice in the Czech Republic). From the rental theory viewpoint, formula (6) undervalues forest land as it does not take into account the first rental effect of existing stands, it takes into account only future rental effects after the rotation period.

For example, if the net gain (net rental effect) from one hectar of a cleared forest is €4000, rotation period is 100 years and discount rate 3 % (i.e. 0.03), the value from formula (6) is calculated as €

$$C_F = \sum_{u=1}^{\infty} \frac{r_u}{(1+i)^u} = \frac{r_u}{(1+i)^u - 1} = \frac{4000}{(1{,}03)^{100} - 1} = \frac{4000}{19{,}2186 - 1} \approx 220$$

The final value of one hectar of forest land also means that if we deposit €220 into a bank with the annual interest rate of 3 %, then after 100 years an amount of €4228 can be obtained. This amount enables to use €4000 and the rest of €228 can be left deposited in the bank to “produce” in another 100 year period the same yield.

Supposing that the rental effect €4000 after 100 years will be obtained only once at a time, then the forest value would be $4000/1.03^{100}$, i.e. approximately €208, which is the amount that, if deposited at the moment of valuation into a bank, will bring an amount of €4000 over 100 years with a 3 % interest rate. The difference with the value produced by (6) is €12, which is the amount that expresses the rental effect after 200 years and the following. As can be seen, the influence on value is very small, even with a low discount rate.

If in the same example a 10 % discount rate was used, then the value of one hectar would be €

$$C_F = \sum_{u=1}^{\infty} \frac{r_u}{(1+i)^u} = \frac{r_u}{(1+i)^u - 1} = \frac{4000}{(1{,}1)^{100} - 1} = \frac{4000}{13780{,}6 - 1} \approx 0{,}29$$

and practically the same minimal amount would be achieved as a lump-sum yield after the first 100 years.

The values obtained show that they are heavily dependent on the time factor, as the formula supposes that the first benefit of €4000 will be obtained after 100 years and then after another 100 years etc. The formula thus supposes that we evaluate a clear-cut land with no stand. The formula also omits the fact that some costs must be spent for reforestation. Borrowing some money amount of, let us say, €200 on a 10 % interest rate for 100 years would mean to repay a devastating amount of €2.76 million. That is why in forest management before the World War II maximally 2 % discount rates were allowed.

To estimate the natural resource value under a limited interval of use (which is the case of exhaustible fossil and mineral deposits), then under the assumption of a constant *r* and *i* the following formula can be used

$$C_v = r.\sum_{t=1}^{T} \frac{1}{(1+i)^t} = \frac{r\left[(1+i)^T - 1\right]}{i(1+i)^T} \qquad (7)$$

This rather complicated scheme can also be reformulated as

$$C_v = \frac{r}{i}\left[1 - \frac{1}{(1+i)^T}\right] \qquad (8)$$

Comparing (8) with (5) we can see that it is composed of *r/i*, corrected by the expression in brackets, whose influence is determined by the discount rate and by the life-time of extracted deposit stocks.

For example, if we are to value a mineral resource deposit that has the stocks for 50 years and the annual net rent is €1000, then with a 10 % discount rate the value of the mineral deposit will not be €50,000 (50 years x €1000) and it will not be €10,000, as it was in the case of renewable natural resource by formula (5). Nevertheless, with a relatively high discount rate of 10 % the value of the deposit will be only slightly less than €10,000, because, as we know from the preceding part, with a 10 % discount rate after 50 years economic values are near zero.

$$C_v = \frac{r}{i}\left[1 - \frac{1}{(1+i)^T}\right] = \frac{1000}{0{,}1} - \left[1 - \frac{1}{1{,}1^{50}}\right] = 10000 \bullet 0{,}9915 = 9915$$

The above given four formulas are the main approaches to natural resource valuation on the basis of the net rent from their use. Some other aspects of natural resource valuation will be mentioned in other parts of this monograph.

2.4. Some elementary concepts from the field of valuation

value

The central concept. It has many meanings in different human activities and professions. Generally it means something valuable or desirable (socially, etically, economically) and expresses some criteria for valuation (normative activity).

economic value

Economic value is a value expressed in monetary terms. It is explained differently by different economic schools. Generally, subjective and objective concepts of economic value can be distinguished. The subjective value is determined by an individual's preferences (utility) that subjective economics accepts as exclusively economic. The objective value is determined as a relation between individual and group preferences on one side and necessary costs for satisfying some human wants. Both approaches are anthropogenic in the sense that positive value is determined exclusively by utility for humans.

Use value

Use values derive from the actual use of a natural resource and/or the environment. For subjective economics, use value is an ability of a thing to satisfy individual wants. Beside direct use value, an option value is also defined (preferences to use the environment in the future) and bequest value (a willingness to pay to preserve the environment for the benefit of one's descendants). In subjective economics, beside use value also non-use value is defined (not used directly for the valuing individual but valuable for other human individuals). For the objective concept of value, use value is an ability to satisfy human needs (not only individual, but of other humans as well).

Non-use value

Non-use value suggests non-instrumental values which are in the real nature of the thing but associated with actual use, or even with the option to use the thing. It reflects people's preferences, but includes a concern for, sympathy with and respect for the rights or welfare of non-human beings.

Market value

Market value is a synonym with common or standard price in given space and time.

Market price

Market price is a specific result of market transactions among a seller and a buyer. Prices are means for transferring all goods and services on a common measuring basis.

Cash flow

Cash flow means a revenue or expenditure. Revenues are positive (incoming) cash flows, expenditures are negative (outgoing) cash flows.

Opportunity costs

is what people would be willing to pay for the alternative they go without because a particular project or policy is chosen.

Intrinsic value in nature

Intrinsic value is a product of belief that nature and its resources have a positive value as an environment for life, independently of humans, irrespective of any use that humans make of them now or in future, and independently of human preferences, irrespective of any feelings of satisfaction that humans might have from knowing that the resource exists. Non-human nature possesses intrinsic value as it has been capable of being inherently valuable for life.

Time

Time *t* refers to a precise point in time, normally in relation to the present, or the time at which a series of cash flows is expected to begin. Thus $14.^{00}$ on 31st May 2016 is referred to as $t = 10$, if the present time is $14.^{00}$ on 31st May 2006 .

Natural resources

Natural resources are those sources and powers of nature that are or can be used by human individuals for production or consumption. The term resources is used synonymously with factors of production. There are many classifications of natural resources. One fundamental property concerns the reproducibility of a resource stock, the extent to which a resource exhibits economically significant rates of regeneration. Where the rate of resource regeneration is significant we describe the resource as being renewable; otherwise the resource is non-renewable (deposits of fossil or mineral resources).

Environmental resources

Environmental resources provide a broader set of services than is recognised in economic analysis; environmental resources play a multifunctional role. These are all resources that create ecosystems and that had and have a decisive meaning for the life on Earth. While natural resources cover only one from the four main functions of the environment, environmental resources cover all four functions (source of natural resources, landscape, sink, life-supporting role). Ecosystem means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (Convention on Biological Diversity, 1992). Ecosystems not only are the source of desired materials (food, wood, fish production, renewable resources), but of utmost importance are their life-supporting services (healthy natural environment supplies clean air, clean water, rainfall, ocean productivity, fertile soil, waste processing, buffering against the extremes of weather, regeneration of atmosphere).

By natural resources in economics, generally the marketed parts of environment are understood, while by environmental resources the non-marketed sources of environment.

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Chapter 3 Environmental (≈Pollution Prevention) Economics

Throughout most of their history, humans used renewable natural resources for their survival (food as a source of energy for human individual, combustion of wood and forms of biomass). The industrial revolution that started thanks to technological development at the end of the 18th century enabled during the past two centuries the rise of modern market economies that technologically rely especially on the usage and combustion of fossil fuels and led to extremely extended possibilities of material production. Market economies produce enormous amounts of different products, but they have been doing this mainly at the expense of destroying the life-supporting role of biosphere and thus threatening the future existence of humankind.

The usage of fossil fuels started to change the ecological equilibrium of the Earth, as the annually consumed amounts of these fuels had been created over millions of years. The carbon that was for millions of years binded to the organic matter is nowadays released with an extreme speed into the atmosphere as a greenhouse gas and contributes to global climate changes and to intensifying climatic disfunctions.

The extraction and combustion of fossil fuels are connected with many other externalities (damages on human health and ecosystems) that were disregarded in the last two centuries and many of them have been disregarded up to now. The exclusion of negative impacts from the extraction and combustion of fossil fuels in the prices of produced energy is one of the reasons why the usage of fossil fuels seems to be more efficient compared to the energy from renewable energy sources.

Definition of externalities

***Externalities or external effects* are defined differently by different authors, but in substance, they reflect the uncompensated impacts of human individuals on others and on nature.** Externalities are such costs and benefits (in the case of positive externalities like the pollination of flowers in a private garden by the bees of a neighbouring bee-keeper) that have impacts on other humans and on the environment and are not included in the costs of their creators. Externalities or external costs indicate that they are uncompensated by market impacts on others and on nature (the existence of externalities is thus one source of market failure). Sometimes externalities are defined as differences among the social and private costs and benefits of an economic activity (economic agent).

In the 1920s, the concept of externalities was defined by A.C.Pigou, who explained the concept in such way that rational self-interested individuals often try to externalize part of their costs by transmitting them on the environment and on society, which causes wrong allocation of resources (Pigou, 1950). Non-optimal allocation of resources leads to exhausting, damaging and destroying public environmental resources in the form of reducing their quality and quantity.

Negative externalities arise if somebody causes some damage to somebody else (to humans, environmental medias) and does not compensate those who are damaged. Negative externalities are very often the case in industrial economies and are primarily linked with utilizing and devastating environment and its resources. **Theory of externalities is a basis of environmental economics**, which, as a branch of neoclassical economics, tries to find an equilibrium among the level of economic activities and their negative external impacts on environment and human health.

The concept of externalities is very often reduced to inter-personal relations. Such reduced concept fits the neoclassical assumption of independency of economic system on nature. A newer concept of externalities includes both uncompensated impacts, i.e. on other individuals and on nature as well (especially from the viewpoint of damaging the life-supporting functions).

In this treatise, externalities are explained in historical context. Externalities are defined as both external effects already compensated for by some instruments (internalised) and externalities uncompensated for (which are the main topic).

Internalising externalities in the world and in the CR

The majority of environmental problems have emerged since the beginning of the industrial revolution and especially in the last decades due to the failure of market economies in internalising externalities. In other words, market economies fail in valuing the environment and environmental resources, in valuing environmental quality changes (Seják et al., 1999). **Environmental impacts of human activities are not fully internalised in economic calculations of individuals and in cost-benefit analyses of public projects. The result is that too many human activities "produce" freely negative externalities,** i.e. produce damages on the environment and human health, while only few activities produce positive externalities.
The most damaging externalities arise due to production and consumption of fossil fuels. The production and consumption of these energy sources is connected with many negative external effects:

- appropriation of natural or seminatural (forest, agricultural) land,
- destruction, degradation and contamination of soils,
- destruction of hydrological and hydrogeological regime of surface and underground waters,
- contamination of surface and underground waters,
- erosion of stability of natural slopes,
- violation of ecological equilibrium of the region,
- violation of scenic landscape,
- change of microclimate,
- increase of illnesses,
- decrease in the level of living,
- decrease of property values,
- increase of transportation and changes in infrastructure,
- reduction of recreational possibilities.

Electricity and heat production are connected with the following externalities:

- emissions of particles and gases with negative impact on human health
- occupational diseases
- impacts on property, harvests, forests, waters and natural ecosystems
- impacts on global warming
- noise impacts
- appropriation of land for waste dumping.

The complete list of externalities from the production and consumption of fossil energy would contain hundreds of items.

The level of internalizing externalities in the world is relatively very low, although negative externalities are endemic in today's economies. As the primary reason for this unsatisfactory situation, the difficulties in measuring and quantifying the externalities are cited. Many environmental relevant externalities are difficult to be quantified. Another, ethically problematic, reason is a low willingness of economic agents (individuals and enterprises) to support revealing the adverse externalities, arguing that their internalization prevents faster economic growth. Such argumentation is clearly unsustainable, as the postponement of externality internalisation leads to much higher damages and respective compensation and prevention costs.

For example, in the case of the coal based electricity production and consumption in the CR, only a small fraction of real externalities are internalised (in the form of emission charges, some payments for extraction of coal etc.). The full internalisation of external costs would increase the price of electricity by approximately one hundred percent (from CZK1/kWh to CZK2/kWh).

Environmental economics as a scientific discipline started to be developed since the 1950s and the 1960s. There are some rare earlier works, like the treatise of A. Pigou (1920) on externalities, but such foretime works did not find any continuators. The concept of externalities was introduced by A. Marshall in 1890 (as a market external, non-payed effect), the concept of negative externalities was introduced afterwards by A. Pigou (1920), who showed that externalities can substantially influence the welfare of affected individuals.

In economic literature of market economies, environmental problems started to be discussed in the second half of the 20th century. Referring to Marshall and Pigou, the central category became the category of externalities. The first broader treatise on externalities was presented by Kapp (1950), who showed pervasive negative impacts of economic growth on environment. Social costs, that are defined as all direct and indirect non-payed for and uncompensated for damages to the third party (public) from economic activities, are the core of his analysis. He mentions different costs that cause the corrosion of materials, threaten the life of flora and fauna and create problems with the quality of drinking water.

A useful distinction among private and public externalities was made in the work of Hartwick and Olewiler (1986). A private externality is understood as a bilateral problem that incorporates only several individuals and where it is possible to identify the author and the level of the negative external effect. By public externality, an externality with broader public impacts on many individuals is understood. Private and public aspects are important from the viewpoint of the form of internalisation. Public externalities are difficult or impossible to solve by private actions. Here the government's role is necessary. In the case of private externalities, government should only create the relevant legislation for internalisation by private persons.

From the very beginning, environmental economics was treated as economics of environmental pollution. Only one from the four main functions of environment was solved (assimilative capacity of environment as a sink). From this viewpoint, it would be more concise to talk about the pollution prevention economics.

Public goods as a form of market failure

The majority of goods produced in market economies have the character of ***private goods***. If you buy a sandwich or some other food, then by paying the price you exclude all other consumers from the consumption of that goods (excludable goods). At the same time, you compete on the market with others to buy such goods (there is a rivalry among the competing consumers). Private goods can also very often be perfectly divided (divisible goods). The typical examples of private goods are bread, clothes, renting the flat, housing land etc. The basic characteristics of private goods are excludability, rivalry or depletability and divisibility.

Many environmental resources have the characteristics of ***public goods***. Wilderness areas have the property that, as long as the use rates are not excessive, ***they are not divisible***. Most indivisible goods are also non-excludable. If one person consumes the services provided by a visit to a wilderness area, that does not prevent others consuming those services as well. ***There is no rivalry*** between the consumption of different individuals provided that the overall rate of usage is not close to some threshold at which congestion occurs (services of wilderness are indivisible). You cannot be exluded from the services of lighthouse, once it is provided to anyone, even if you refused to pay for its construction. Another example of public goods are clean air, clean water, national defence, police etc.

In case of public goods, the markets fail. The probability of markets existing to provide or conserve public goods is extremely low, even where their existence would yield positive net benefits.

3.1 Relations between economy and environment

Every economy is a production and consumption of goods and services. It is supposed that production is realised in the firms, consumption in the households. From the firms, there is the flow of goods and services toward households, and from households labour force is hired into firms. The majority of economic literature deals with the analysis of interactions among production and consumption and respective flows. Macroeconomics concentrates on the total levels of activities and flows, e.g. how to keep the production on the level that assures highest employment. Microeconomics deals with the structure of production and consumption activities, e.g. with the questions why some goods are produced on higher or on lower levels.

Substantially, less attention has been devoted to the relations among economy and environment. These relations became the topic only in the last two decades. The majority of current studies come from the assumption that the environment provides humans with a wide range of economically valuable functions and services (Turner et al., p. 17):

1. **a natural resource base (renewable and non-renewable resources),**
2. **a waste assimilation capacity,**
3. **a set of natural goods (landscape and amenity resources),**
4. **a life support system.**

Nature is a source of natural resources (as inputs into production and consumption). An example can be mineral deposits, forests or animal populations. Nature is also an environment into which all wastes are emitted and deposited. Nature is also a source of landscapes and amenity goods. And, last but not least, nature provides the life-supporting functions and services.

At present, all these four main functions are mutually competitive, i.e. there is a substitutional relation among them. For example, a river can serve as a source of industrial or drinking water, it is an environment into which the wastewaters are discharged, it is an environment for recreation, for fishing etc.

For centuries, nature has been fulfilling all these functions in a complementary way. With growing levels of economic activities and with growing numbers of human species, the thresholds of nature assimilative capacity have been violated, these four functions became competitive, and nature and its ecosystems became a scarce resource, with the trend of a growing scarcity.

3.2 Economic growth and environment

Some authors argue that economic growth and the quality of environment are incompatible concepts, that they are substitutional. But the relations among both entities are more complicated, because they are both substitutional (from the short-term viewpoint) and complementary (from the long-term viewpoint). The environmental impacts of economic growth are determined by three main factors:

- If there are no changes in economic activities and economic growth involves an increase in material and energy inputs, the potential for adverse environmental impacts is greater.
- If the growth process is characterised by qualitative changes and substitution effects. Higher output value may not necessarily require higher quantities of inputs. Moreover, as relative resource scarcities change, to the extent that these changing scarcities are reflected in changing prices, substitution effects will take place on both demand and supply side of economic activity. With higher economic level, primary (resource extractions) and secondary (manufacturing industries) sectors are decreasing and tertiary sector (services) increases. Services have a lower level of discharges of potentially damaging pollutants.
- With higher economic level, the share of cleaner technologies increases.

It is also important that in wealthier society the people’s willingness to pay for cleaner environment increases. In democratic societies this must be expressed in relevant policies. Environmental policy that supports cleaner activities and penalizes polluting activities can help in structural changes. Also consumers can substantially help by preferring environmentally friendly products.

Analyses from advanced market economies show that environmental abatement costs achieve among 1-2 % of GDP and are not decelerating economic growth.

From the long-term viewpoint it is then clear that qualitative economic development and sustainable development are complementary.

At the same time, it is necessary to underline that the dependency among economic growth and reducing pollution levels is not automatic. It can be achieved only with strict environmental policy.

3.3 Economically optimal quality of environment

In setting the economically optimal level of environmental quality we can often meet an approach talking about the economically effective or optimal level of pollution. But the concept of the economically effective or optimal level of pollution is ethically problematic as people have the right to have clean environment. It is thus more convenient to talk about economically effective or optimal level of pollution control (pollution abatement).

By pollution we understand residual flows of wastes from human activities that determine the load upon the environment. The damage done by this load depends on the capacity of the environment to assimilate the waste products (absorbtive or assimilative capacity of nature). If the emission load exceeds the absorbtive capacity of the environment, then the pollutant accumulates in the environment and causes damages on human and ecosystem health.

A part of pollutants is absorbed by the environment and they do not accumulate (e.g., some organic pollutants are transformed by resident bacteria into a less harmful inorganic matter, carbon dioxide is absorbed by plant life and the ocean ecosystems).

For some pollutants, the environment has little or no absorbtive capacity (stock pollutants); the examples include nonbiodegradable bottles, lead and other heavy metals, persistent organic pollutants like dioxins or PCB (polychlorinated biphenyls). By pollution we can understand those emissions that exceed the absorbtive capacity of the environment. An extreme case is that in which the absorbtive capacity is zero, as seems to be the case for some synthetic chemicals and a number of heavy metals. Metals such as lead, arsenic, mercury etc. accumulate in soils, aquifers and biological stocks, and subsequently in the living species including human bodies, causing major damage to human health. Persistent organic pollutants, such as PCBs, DDT and dioxins, have similar cycles and effects.

A damaging pollution has negative impacts on natural and environmental resources. For example, it decreases the harvests of renewable resources (reduction of soil fertility, reduction of crop harvests) and it reduces the quality of environmental resources (pollution of air, waters, reduction of biodiversity etc.).

From the viewpoint of casual relations among pollution and damages, we can differentiate:

- Pollution caused by the flow of emissions (the “purest” example of flow pollution is noise pollution that lasts only during the noise effect)
- Pollution caused by the stock pollutants (damages are the function of pollutant stock).

Damages are very often the result of a combination of both impacts. The majority of pollutants are probably mixed cases, with the nature of the mixture varying over time and space.

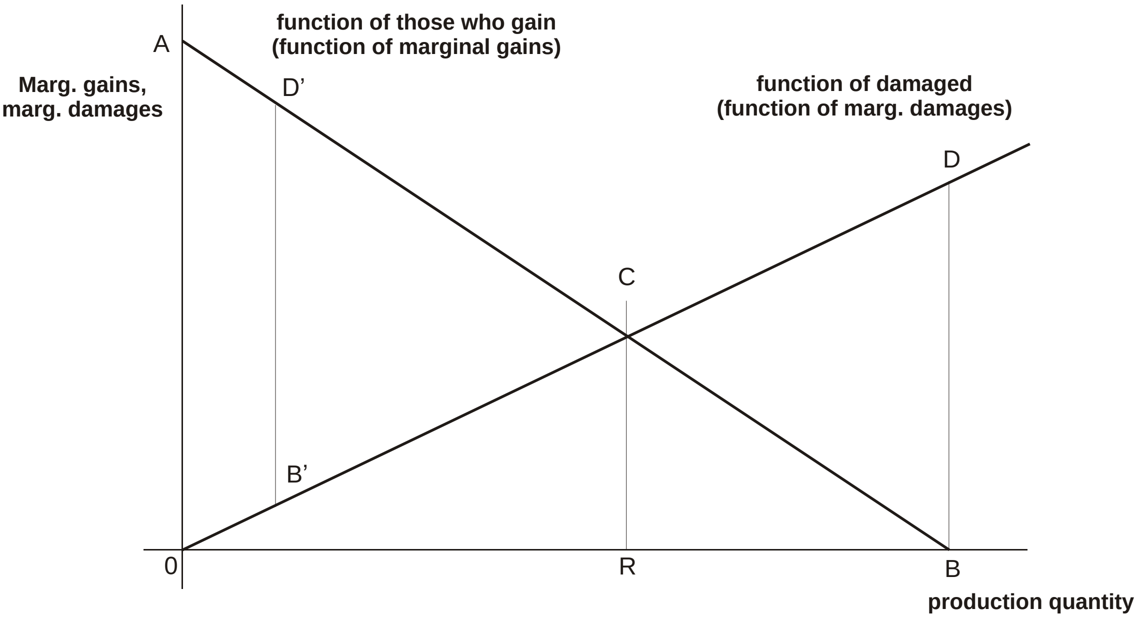
Pollution damages can be local (e.g. noise, light, visual pollution flows), regional (e.g. sulphur dioxides) or global (e.g. carbon dioxide and other greenhouse gases). Global pollutant damage is related to pollutant concentrations in the upper atmospheric levels.

Emission sources can be stationary (such as power stations, pesticides in agriculture) and mobile (vehicle traffic pollution).

In order to produce and consume some useful products, people are willing to bear some risks of pollution up to the level where the marginal benefit from consumption equals to the marginal damage from pollution. Supposing flow pollution we can say that the level of damage is a function of the flow of pollutants. The economic efficiency of polluting production can be characterized by the maximisation of net benefits (as a difference between benefits from production and damages from pollution).

According to neoclassical marginal analysis, the economically effective level of pollution can be identified in the situation where the marginal benefits from polluting production equal with the marginal damages from pollution. From only economic viewpoint it is not necessary to remove all pollution (all negative externalities). The economically optimal level of polluting activities exists and it is not zero level. It is shown in the following chart 3.1 where on axis X is the quantity of production and on axis Y are the marginal benefits and damages (for simplicity we suppose that there is a functional relation between the level of production and the level of pollution).

chart 3.1



The polluting producer and the consumers of his production are profiting while those who are damaged can be all inhabitants. From the viewpoint of the producer, it is optimal to produce level 0B, where the marginal gain decreases to zero. For the afflicted persons, the optimum is zero production with zero emissions.

If the producer is not committed to pay any compensations for pollution, then he develops production on level 0B, where the gains from production are maximal. In this situation:
Gains for producers and consumers = 0AB
Damages of afflicted individuals = 0DB
Net social gain = 0AD'B' (0AB minus 0DB).

If the producer is made (by legislation) to reduce the level of production from B to R, the social gain increases, because then
Gains for producer and consumers = 0ACR
Damages for afflicted individuals = 0RC
Net social gain = 0AC.

The economic optimum is achieved at the level 0R, where the social gain is 0AC, while the damages create 0RC. The total social net benefit is positive at the level AYC. The level of production and pollution 0R is tied with the price Y. It is the price for pollution on the level of R. Neither higher nor lower production and pollution is effective because with other levels the difference of gains and damages is lower. If the production was closed then the environmental damages would be zero, but society would lose the gains from the production.

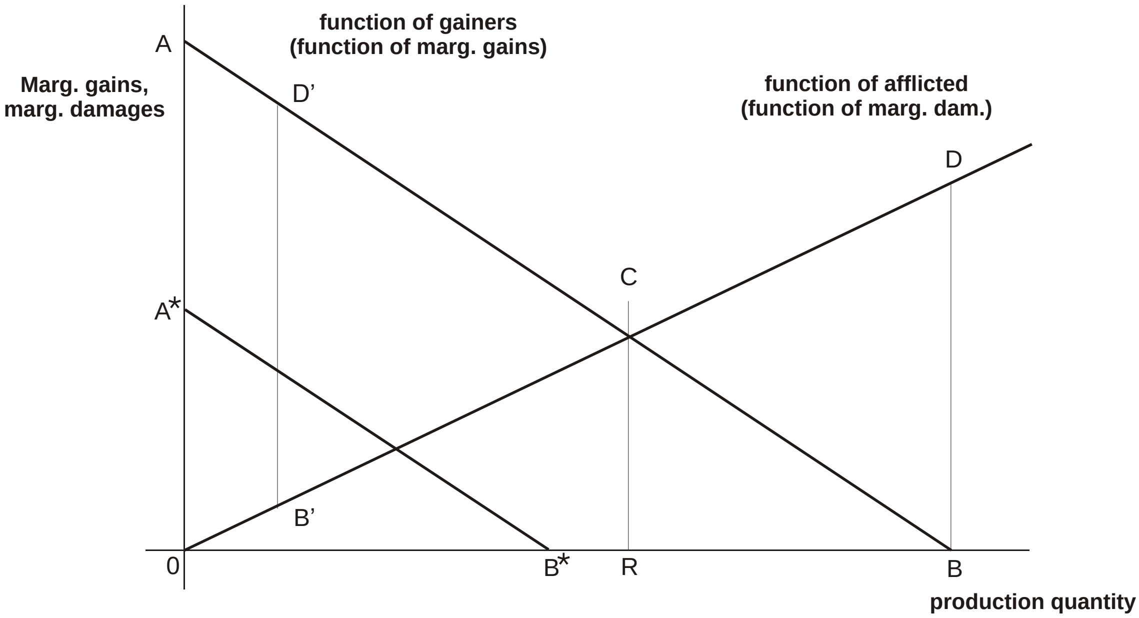
These conclusions are valid under the assumption that there is a constant relation among production and emission level, i.e. that there exists a technology that requires some time period for emission reductions.

The practical solution in emission reductions consists either in

- continuing the use of the existing production technology and reducing emissions by end-of-pipe environmental technologies which are increasing the price of production and higher price will lead to lower production level,
- or installing of a new technology that complies with the emission limits or is even clean (reduces the emissions to zero).

Clean technologies are usually rather expensive and push the price of the production up. The result situation is shown in chart 3.2:

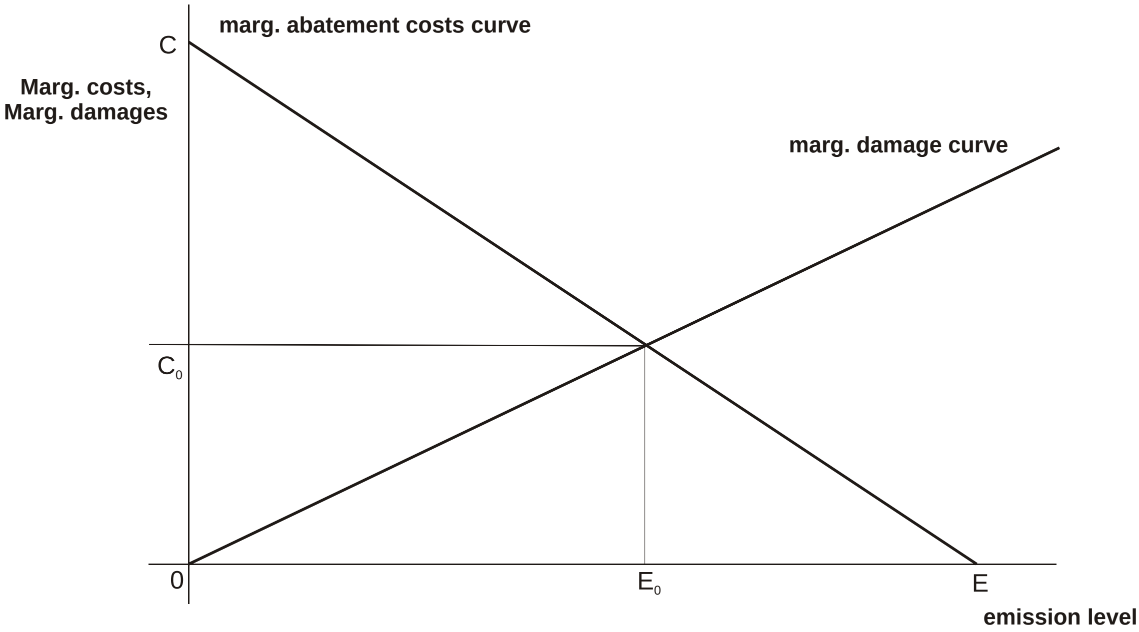
Chart 3.2



From the chart we can see that the installation of clean production led to the decrease of production on the level 0B*, i.e. led to a deeper decrease than is the optimum. The total social benefit is then 0A*B* (because there are no damages). However, this gain is lower compared to the level of 0R, as the surface 0AC is bigger than 0A*B*.

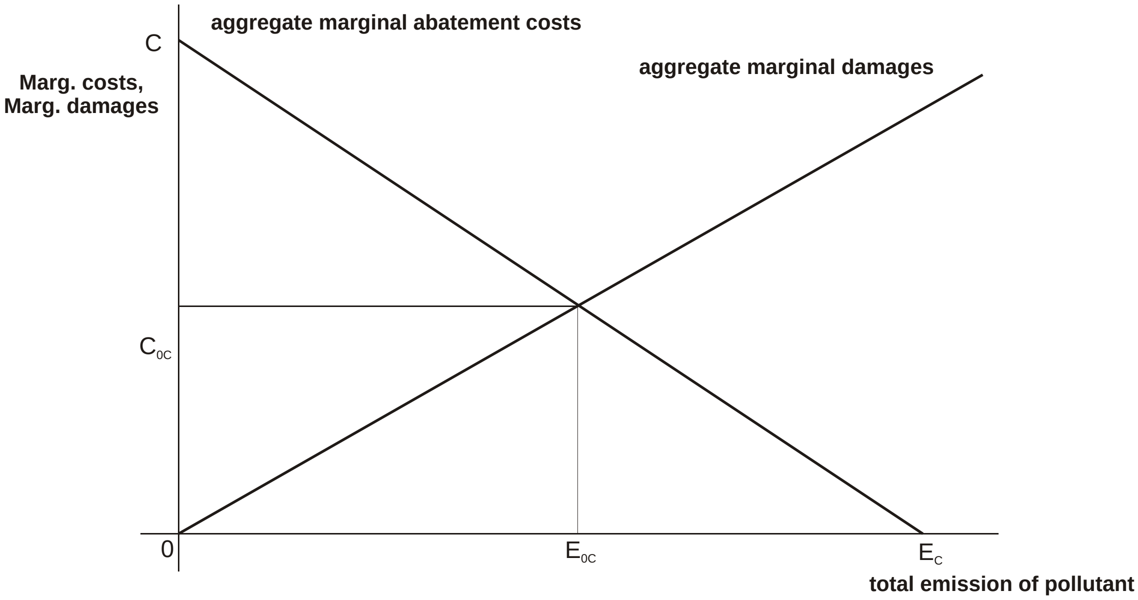
In any case, environmental protection requires a cost for emission reductions, which is the price for cleaner environment. Chart 3.3 shows that reducing the emission level to $0E_o$ (that corresponds to production level 0R) is tied with the price C_o, while a full emission reduction requires the price C.

chart 3.3



A similar chart can be drawn for aggregated emissions of some pollutant from all emission sources. Such chart contains macroeconomic information, as it shows the level of emissions and the economically optimal emission level that is determined by the crosspoint of both curves (marginal abatement cost curve and marginal damage curve).

chart 3.4



Up to now, we supposed that the damage level is a function of a pollution flow and that it depends on the pollutant flow in time. Nevertheless, there are also persistent pollutants, which emitted into environment survive for some time period and transfer through the food chains into plant and animal species including human bodies. Traditional economic analysis does not take such stock pollutants into account.

In the case of a persistent pollutant the emission flow in time is important and the stock as well. Most stock pollutants do not persist perfectly, as the pollutant has a limited "life". Then the stock at time t will be the sum of all the previous pollution emissions less the sum of all the previous pollution decay. The emissions of a persistent pollutant in individual time periods are mutually dependent and the stock increases in individual time periods by the difference among emissions and decay. Then the production with persistent pollutant emissions should be reduced to the level where the level of pollutant stock does not increase.

3.4. Pollution control policies

All economic activities involve the production of waste in either energy or mass forms. Perfect recycling of wastes is impossible. For a very large class of external effects, government intervention is necessary (private bargaining among a polluter and an affected party is effective only in the cases where the property rights are strictly defined and the transaction costs are zero). The pollution targets are generally set on the base of health risks. Once a pollution control target has been selected, economic reasoning still has a role to contribute in designing the programme to achieve that target. The government may have incomplete information about either the costs or the benefits of various types and levels of intervention. The type of instrument will depend upon the form which uncertainty takes.

The government can apply the following controlling systems over the permissible quantity of emission:

1. quantitative control – **command and control** (CAC) instruments are the prevalent method of pollution control. The use of CAC instruments can be efficient, as it is in principle possible to choose emission standards for each firm in order to achieve the total emission standard. This requires that the marginal cost of abatement be equal over all firms undertaking abatement. However, this is very unlikely to be achieved in practice. To do so, the control authority would need to know the abatement costs function for each firm. Controlling authorities have not enough information and firms have strong incentives to not disclose information. Then some arbitrary method of distributing an abatement burden over firms is applied and the result is inefficient.
2. taxes and subsidies can be applied, for example in the form of **emission payments.** A tax on pollutant emissions is the standard form of instrument advocated by economists to achieve some preset pollution target. In order to achieve an economically efficient level of pollution, the tax should be applied on each unit of pollution emitted, at a rate equal to the monetary value of marginal pollution damage at the optimal level of pollution ($0C_{oc}$ in our example). Such tax will internalise the externality by bringing private prices into line with social prices. It is clear that also under this approach the controlling authority does not know the specific shape of both curves, so the specific level of emission payment is set by expert estimations and later corrected, in order to have a stimulative effect.
3. **subsidies** for pollution abatement are treated as if they were the same type of instrument as taxes. However, long-run effects of subsidies may be different from the long-run effects of taxes, given their different distributional implications.
4. transferable (marketable or **tradable**) **emissions permits** involve: 1) a decision as to the total quantity of pollution that is to be allowed, 2) a rule which ensures that any

firm is allowed to produce pollution only to the quantity of emission permits it possesses. Any emission beyond that level is prohibitively expensive (by fine or other penalty), 3) a choice by the control authority over how the total quantity of emission permits is to be initially allocated (in total level of $0E_{oc}$ in our example), 4) a guarantee that emission permits can be freely traded between firms at whichever price is agreed for that trade. Market should assure that any firm buys so many permits for a price to equate with their marginal abatement costs, which finally are equal to marginal damage.

But if market is not competitive, but e.g. oligopolistic (i.e. on one market side there are only two or three subjects), then emission trading need not be socially effective as it can lead to deliberative decrease of production and to higher prices (see e.g. Ferhtman, Zeeuw, 1996).

Economists argue that economic forms of solution, i.e. 2. and 4. method of solution are more effective and economical compared to administrative forms. Although the difference between the administrative and economic instruments can often be rather unclear, there is one quite distinctive point - the nature of the instrument. While administrative instruments can be explained as constraints, which create no space for economic decision-making, then economic instruments, as an economic form of human behaviour stimulation, do create such space. From the point of view of the allocation of resources, an optimal solution is more feasible when the behaviour can be flexible. The introduction of economic instruments is just such an attempt to reach such flexibility, introducing into the decision-making framework a price-quantity scheme.

Such space for economic decision-making follows from the fact that individual polluters normally have different levels of marginal abatement costs (different marginal abatement cost curves); yet this information is not disposable for environmental authorities responsible for creating and enforcing the environmental regulation.

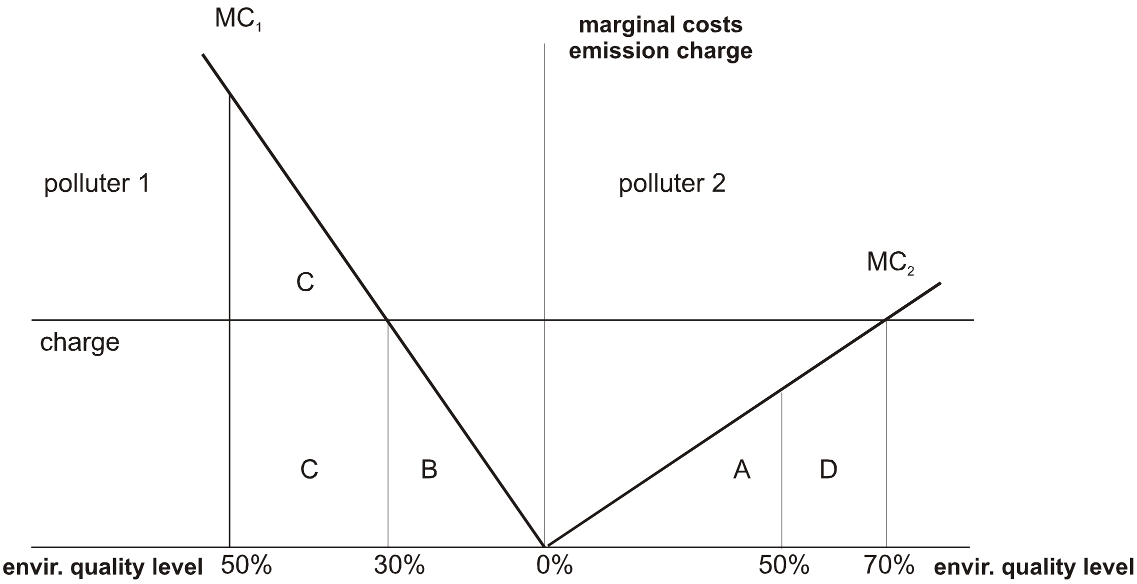
Above all, the contrast between an economic incentive mechanism and traditional "command and control" (CAC) approaches is that the latter do not provide incentives to reduce the quantity of releases below permitted levels or to improve the quality of the releases of pollutants beyond permitted levels. Under a pure CAC approach, sources view all releases below permitted quantities or above permitted quality as costless and have no economic reason to act until new regulations are issued.

Direct regulatory approaches generally are most effective when all the affected sources of pollution have similar emission characteristics, environmental impacts, and pollution control possibilities and when the regulators have as good a knowledge of the available abatement opportunities. These conditions do not apply to most of the current environmental problems.

There are many non-point, heterogeneous and/or mobile sources which contribute with high amounts to the general level of pollution. In such conditions a direct regulatory approach may be much more expensive and less effective than economic incentives. Particularly for diverse sources, individual firms and households are more likely than regulators or legislators to have the knowledge to choose the most effective pollution control techniques for their particular situation. Regulatory bodies are not likely to have access to the same range of knowledge. Regulatory approaches further fail to provide an incentive to adopt pollution controls other than those specified by regulators, even if they would be more effective.

According to economic theory, the application of economic instruments (environmental charges, taxes, tradable permits etc.) has the potential of higher cost-effectiveness than the administrative, legislative solutions by means of environmental standards (setting maximums for allowable emissions).

In the following chart it is shown that the application of market-oriented economic instruments is cheaper, from the social cost viewpoint, than the administrative solution by means of some uniform environmental standard. Suppose that there are two polluters existing which have approximately the same production capacity, but different marginal abatement costs.



The environmental authority can regulate the pollution by means of an administrative approach, enforcing a standard in the form of, for example, 50 % reduction of pollution for both polluters. Total costs for both polluters will then be represented by the surfaces A, B and C.

If the environmental authority uses the economic solution by means of emission or product charges, then both polluters have the space for economic optimization evaluating what is, for them, more convenient. Whether to pay the charge or to install some cleaning equipment.

With the charge level shown in the diagram, for polluter 1 it is rational to reduce only 30 % of pollution, because then his marginal abatement costs are higher than the charge. For polluter 2 the same comparison shows the optimum environmental quality level at 70 %. As both polluters are of the same capacity, the total environmental improvement creates 50 %. The cost savings from the application of an emission or product charge (compared to a uniform 50 % pollution reduction standard) are represented by the difference between the surfaces C and D.

From the above chart it results that the static efficiency gains from the use of economic intruments arise in situations where polluters face different opportunities for pollution abatement, or, in other words, have different marginal abatement costs. The efficient, cost-minimizing, pattern of pollution abatement would require greater reductions in pollution by those sources or polluters for which the cost of each unit of pollution abatement was low, and would impose less stringent levels of abatement on sources facing a high marginal cost of abatement.

The substantial fact is that the above mentioned comparison of economic and administrative ways of environmental protection is **based on static timeless concept** which assumes immediate reactions of agents to given price. This comparison is based on assumption that administrative solution needs a uniform decrease of emissions from all emission sources and on this assumption it concludes that economic forms which respect individual economic conditions of individual sources are more efficient than administrative forms. These are two important assumptions which cause the static analysis substantially conditioned.

A Pigouvian environmental tax is in pure form an emission payment which should compensate losers for their damages caused by pollution. Such payments would have purely compensating character and would not serve the main goal of environmental policy, which is prevention. Above all, a Pigouvian solution is a concept of static efficiency, but in real economy an accommodation to new prices is not immediate and in the economy with limited resources it needs some time period for respective technological changes. Then during such an implementation period the pure economic solution needs not only the costs for emission payments, but the costs for technological changes as well. But a direct control by means of emission standards needs only the costs for technological changes (abatement costs). It means that administrative control is cheaper for polluters than the control by emission charges.

A pure economic solution by means of emission charges (but without using individual emission standards) was not used in any market economy. In most cases mixed solution with both standards and charges was used. Charges were low comparing to marginal social damage or marginal abatement costs and supplemented by individual emission standards.

From the theoretical point of view, apure economic solution by environmental taxes based either on marginal social damage or on marginal abatement costs contains some unanswered questions:

1. Pigouvian environmental tax compensating losers for their damages is rather theoretical framework which can hardly be used in environmental policy due to a lack of information on marginal social damages and, above all, Pigouvian taxation with its compensating character does not serve to the main goal of environmental policy, which is prevention.
2. In practical environmental policies, emission charges were mostly based on the political Baumol-Oates approach, deriving levels of charges from marginal abatement costs which are necessary for achieving politically determined environmental standards.
3. Both Pigouvian and Baumol-Oates approaches are static concepts assuming immediate reactions of polluters to emission charge. In practice it is necessary to give polluters some time period for implementing technological changes and during this period polluters have to pay emission charges and invest into environmental protection as well. The procedure is more expensive for polluters compared to direct control by emission standards, in which polluters only have to invest into environmental protection.
4. reallocation of collected charges or taxes to polluters, which can achieve comparatively major economic effects in environmental protection, is forcing the "polluter pays principle". Such reallocations are well known in Central and Eastern European countries from former centrally-planned economy, where they completely failed due to incomplete knowledge of economic parameters by allocator and, above

all, due to misallocations known from the “principal-agent theory”, when allocator substitutes social criteria by self-intrested criteria.

These are probably the main arguments why in practice most economies preferred direct control combined from time to time with environmental taxes, used mainly as a supplementary fiscal instrument.

This also has been the case in the Czech Republic. Emission charges in the fields of air and water protection, based on abatement costs, have been applied already since the late sixties, but in the conditions of a centrally-planned economy they were inefficient. After political changes, the Federal and Czech National Parliaments accepted, during the 1991-1992 term, relatively stringent environmental laws. This environmental legislation was based predominantly on a command and control approach, while a relatively large number of economic instruments have been introduced as well and given a supplementary role. The command and control approach is represented by strict individual environmental standards (emulating EU levels) for any source of pollution, while economic instruments are represented mainly by emission charges constructed on a theoretical background of average abatement costs.

Since 1992 all large and medium **air** polluters have been given a 7 year period to cope with source specific (individual) air emission standards comparable with standards common in the European Union. The polluters not only have to invest into environmental technologies, but have to pay air emission charges as well. While the emission standards were set mainly for the five main pollutants (solids, SO2, NOx, CO, CxHy), *the emission charges were installed for nearly 90 pollutants*, including heavy metals, persistent organic pollutants and VOCs. The base rate of charge was derived from average abatement costs to equalize the economic conditions of polluters with non-polluters. The surcharge is derived as 50 % of basic rate and is applied in case of not complying with the emission standard. In cases of proven abatement projects, 40 % of the charge is deferred during the project. Air pollution charges were increased gradually from 30 % of the full rate in 1992 to 100 % in 1997.

Water effluent charges have two components. The base rate is determined by the cost of abatement technologies (like in the air emission charges) while the surcharge depends on imission situation, i.e. on the damage inflicted to water quality. The deadline for complying with stringent emission standards was the end of 2004.

Charges for waste storage depend on the quantity and category of stored waste. If the dump complies to regulations for operating dumps, the base rate applies with revenue going to the community in which the dump is located. If the dump does not comply, the operator pays noncompliance fees at a higher rate per ton of waste disposed.

Besides the complete emission charges system also the user charge system is applied (for usage of surface and ground water, for dispossession of agricultural land and for exploitation of mineral deposits).

The Czech Republic and especially Poland are said to have the highest number of economic instruments for environmental protection installed in their economies. Emission charges are predominant.

From the above mentioned it is clear that <u>the core of economic instruments</u> for environmental protection is based on <u>emission and user charges</u> (see table 3.1).

Emission Charges in 2013 in the Czech Republic **table 3.1**

Pollutants	tons	Charges in CZK thous.
Air pollutants		
Particulates	**6 787**	**19 992**
Sulphur dioxide	**110 735**	**109 832**
Nitrogen oxides	94 343	69 173
Carbon monoxide	135 086	78 737
Volatile organic compounds	7 613	11 629
Heavy metals	38	338
Ammonia	266	259
PAHs	1	8
Class 1	3	134
Class 2	2 663	4 834
Total	357 534	294 935
Waste Water pollutants		
Waste waters into surface waters in 2012		211 605
Waste waters into underground waters in 2012		2 416
WASTE disposal		
charges on waste disposal in total in 2012	4 526 979	1 479 671
Of which: municipal waste	2 636 694	1 211 064
hazardous waste	189 997	16 541
other waste	1 700 288	252 066

Besides the above mentioned types of environmental charges there are also some charges for the exploitation of natural resources in power. An overview of these charges is given in table 3.2.

User Charges for the Exploitation of Natural Resources in 2012 table 3.2

Charge base	Revenue CZK mil.	Revenue spending
Charges for surface water Determined by cost-plus method, the charge is an element of a permit system, is paid for the consumption of water exceeding the standard limit	3 316 payment for the service of River Basin Enterprises	River Basin Enterprises cover their costs inclusive the cost for environmental activities
Charges for ground water the charge is an element of permit system for taking a volume exceeding the standard limit	373	charges go to SEF to finance ground water protection
Charges for dispossession of agricultural land Charge based on agricultural alternative costs (normative productivity of land unit), increased by environmental factors in protected areas	508.2	75 % state budget 15 % goes to SEF 10 % to municipality
Charges for the exploitation of mineral deposits a)up to 10 % of market value of extracted raw-material	643.5	75 % municipality 25 % state budget

Some *tax differentiation* according to environmental impacts is also applied. For example certain environmentally sound products are included into the reduced VAT. Bionaphta and biogas are tax free. The income and corporation taxes contain clauses that the income of small hydroelectric power plants, wind power plants, solar energy installations, biogas production are tax free within a 5 year period. Real estate tax liberation can be claimed if a change in the heating system or energy saving measurements are made. The environmental tax reform introduced new environmental taxes into the Czech tax system effective from 1 January 2008. Taxation of electricity, natural gas, and solid fuels (i.e. energy products) is applied if the energy products are supplied by the supplier to final consumers or when untaxed or exempted energy products are consumed.

A *deposit refund system* for glass bottles had been established after World War II. It was revitalized in 1992 and its aim today is environmental. About 70 % of all glass bottles are included in the system. The return rate is 70-80 %. In recent years there has been a dramatic increase in different types of plastic bottles (especially PET-bottles) and selected types are already included in the deposit refund system. But in general the problem of waste plastic bottles re-use is yet to be solved.

It turns out, however, that the instruments were not created systematically and often discrepancies exist between their proclaimed and real functions. Some problems are consequences of the instruments being prepared predominantly by lawyers and engineers rather than economists. Additionally, for those involved in formulating new legislation the more traditional administrative mechanisms are more familiar and understandable than market-based economic instruments. Other problems resulted from the previously federal composition of Czechoslovakia, where three governments and three parliaments existed.

Occasionally insufficient courage on the part of authorities to enforce the rather new and nontraditional instruments (for instance stimulating rates of charges for pollution) presents further problems. Similar concerns were also responsible for the introduction of economic instruments being prolonged over a period of a few years which, along with inflation, resulted in the significant decrease of the economic instruments' efficiency.

At present, a new environmental policy, which assumes the application and use of even more economic instruments, is being formed by the Ministry of Environment on the basis of the previous period evaluation. One reason for such a trend is the fact that the system of environmental protection based mainly on administrative instruments is enormously expensive and many experts have expressed their doubts as to whether such a fragile new market economy as that currently existing in the Czech Republic can bear the costs. Besides this, the present mainly administrative system of environmental protection shows numerous functional shortcomings which cause many particular problems that must be solved case by case.

What is the main experience from the several years of intensive application of economic instruments in the Czech Republic:

Due to the differences between the concept of static efficiency and real needs of environmental policy framework, the optimum procedure for implementation of emission payments is:

1. to determine emission or product **charges on the level of marginal abatement costs**, i.e. on the level high enough to stimulate polluters to start with emission reductions. These charges must be combined with the determination of either the global emission standard or even can (but need not) be combined with the determination of individual emission standards and setting the period for their implementation. In the latter case the advantage of economic solution can be realized only under the assumption that polluters which will reduce emissions more than

stated by the individual standard will have a chance to trade the difference with some other polluter which is not able to comply with the standard

2. in order to prefer prevention in environmental policy, it is necessary to entitle polluters for **charge credits at the level of at least 80-90 %** for cases when they started with abatement measures and will implement them during some time period. So, it means that polluters have the right to use their charges for investing into environmental protection.

This procedure eliminates all shortages flowing from the timeless concept of Pigouvian and Baumol-Oates taxation and reflects the necessity to set some implementation period. At the same time it enables to benefit from the economic solution, because the polluter will pay charge only in case that it is cheaper for him than to invest into environmental protection.

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Chapter 4 NON-MARKET ENVIRONMENTAL RESOURCE ECONOMICS

"Capitalism, as practised, is a financially profitable, nonsustainable aberration in human development…It liquidates its capital and calls it income. It neglects to assign any value to the largest stocks of capital it employs – the natural resources and living systems, as well as the social and cultural systems that are the basis of human capital".

Hawken, P., Lovins, A.B., Lovins L.H., Natural Capitalism, p. 5

4.1. Concepts of valuing non-market parts of nature

In the preceding chapters, the methods of natural resource valuation were analysed, i.e. the methods of valuing those parts of nature that are marketed. In this chapter, the valuation methods of non-market parts of nature will be described.

Already in the first chapter it was stated that non-market parts of nature create more than 99.9 % of all plant and animal species, which are estimated at the range of 5 to 30 million. From the broad dispersion of the number of estimated species it can be seen how limited human cognition of living species and their relations in ecosystems is, especially in rich ecosystems like in wetlands, river estuaries or rain forests.

From prehistoric times, natural environment and natural resources had been understood by humans as something they have at their disposal for living and survival. Due to their abilities of thinking they step by step emancipated from a direct dependency on nature and started to take up a supreme position above nature and other living species. This anthropocentric superior position is evidently formulated in the Judao-Christian doctrine, as according to the Bible God told people about nature:

"*Be fruitful and increase in number; fill the earth and subdue it. Rule over the fish of the sea and the birds of the air and over every living creature that moves on the ground.*" (Genesis 1:28).

As long as the population of the Earth was relatively low and human knowledge did not penetrate into the substance of the mass, there were no serious problems in the use of nature.

The situation changed dramatically in the 20th century due to a highly growing population density and due to substantial athropogenic interventions into natural processes. The WRI Report, prepared for the UN (HN, 18 April 2000), states that during the last 100 years the Earth lost half of its most valuable wetlands and natural forests, 60 % of world rivers were dammed and that the continuation of ecosystem loss can have a devastating impact on further human development.

Due to these new facts, the nature, natural environment and natural resources, as well as the global Earth ecosystem, became scarce (resources with positive economic value) so that they cannot be used as freely accessible goods with zero price, but must be given a positive price that will reduce their use on a sustainable level. That is why any positive value assigned to non-marketed environmental goods and services is better than non-valuation in current market economies.

Nature and its resources can be divided into two main groups. One group is formed by material sources on and under the earth surface (land, water resources, forests, mineral deposits) that were throughout centuries used in market economies as economic goods with a positive price. In economic theory, these resources are called **natural resources** and they have been an object of market and property rights as private goods.

They contain potentially renewable resources (such as fertility of land and its biological growth potential, agricultural goods, timber or fisheries) and non-renewable resources (such as mineral fuels, land as a space for construction and development) that were analyzed in the first chapter. They comprise both biological and physical resources (urban and agricultural land, forests, water resources, mineral deposits etc.).

Beside these natural resources, the nature contains countless other resources that serve as natural environment and as life-supporting ecosystems. While natural resources are the source of desired materials, food, energy, space, etc., of utmost importance are the services of ecosystems that are far more critical to human prosperity. A healthy environment automatically supplies clean air and water, rainfall, fertile soil, it regulates the temperature etc. A healthy environment can be characterised by high biodiversity. These **environmental resources** play a multifunctional role and are 'free' in monetary terms (free public goods, natural environment and its ecological quality). Ecologists and environmental scientists have for a long time criticized the tendency of economic activity to degrade and deplete natural environments, and have shown how stability and resilience of ecosystems can be threatened by excessive rates of economic activity.

Conventional interpretations of natural resources ignore a set of productive services offered by environmental resources. These services, for which no financial payment is (usually) made by the user, include:

- waste assimilation and processing by ecological systems
- the direct provision of environmental inputs (such as clean air, water for cleaning and cooling)
- environmental systems maintenance processes, which sustain clean air and water, maintain climatic conditions, regulate soil fertility, support stocks of renewable resources (such as agricultural products, fish and timber) and regulate water flows in river systems and aquifers.

For the minimization of negative anthropogenic impacts on ecosystems, i.e. for a sustainable approach to ecosystems, it is necessary to follow certain basic rules:

1. the stock of renewable resource assets (renewable natural capital) should be managed so as to maintain a sustainable yield of resource services: i.e. harvesting rates should not exceed regeneration rates,

2. extraction or depletion of non-renewable resource stock should be limited to the rate at which renewable resources can be substituted for them (this will keep the zero rate of depletion of all natural resources),

3. production of waste should not be higher than the assimilative capacity of environment.

Achieving a sustainable treatment of nature and environmental resources is connected first of all with the request to stop the use of environment and its services as freely accessible goods and services with zero price.

To incorporate environmental public goods into economics and economic decision-making, this problem must be managed at three levels minimally:

1) at the level of the socio-economic paradigm - ethical basis of valuation (to accept new values going beyond the concept of willingness to pay)

2) at the level of macroeconomic accounting (information) system (greening the national accounts)
3) at the level of operating the guidelines (implementation, through development of democratic participatory institutions, of new economic instruments for value realization).

In many European market economies nowadays, environmental and economic problems exist simultaneously. Sometimes it seems that economic problems dominate, but after some period the local, regional or global environmental problems arise. This evokes a question whether it is enough to broaden the standard market economy model by environmental aspects or whether this standard market economy model should be completely modified. The first approach is represented by environmental economics while the second by ecological economics. According to ecological economics, the economic system is a subset of global ecosystem, i.e. it comes from the request to formulate new economic theory based on this new ranking of ecological and economic systems.

It is clear that one of the main reasons why environmental problems are difficult to be solved is a fact that they arise due to the fact that substantial parts of nature have a character of **public goods** (have the characteristics of joint consumption and non-exclusion; when the goods is consumed by one person, it does not diminish the amount consumed by another person) and that human activities produce **externalities**. Both these characteristics of many environmental goods have meant that their true value (total economic value) has been underestimated or ignored altogether. They have remained unmeasured and unpriced, and have therefore been used inefficiently. Market economies do not take automatically any of these characteristics into their framework. These very problems also produce questions of the necessity of new environmental ethics, environmental modification of national account system, on substitution of economic growth by sustainable development.

All these questions are tied together, because the questions of ethics (values), proper environmental information (that in macroeconomics is covered by national accounting system) and the questions of proper instruments for implementing the principles of sustainability are necessary aspects of real change to sustainable development.

Many ecologists believe that currently the new environmental ethics is necessary as nature embodies intrinsic values that are independent of humans. That is why new strict rules are necessary that will prevent environmentally damaging behaviour of people. Human individuals and economists especially must accept the fact that nature has a determining role in forming the quality of life and that the utilitarian approach to nature must be substituted with a protectionist approach that respects the criteria of a long-term sustainability of life.

With this new ethical view, at least three substantial questions arise:

1) should the new world-view be basically anthropogenic or ecocentric?

2) should the questions of distribution be decided on a utilitarian basis, libertarian basis or on the basis of social (value) contract?

3) should there be individualism or collectivism on the base of ecological values?

One of the main questions of environmental ethics is whether it should be primarily anthropocentric or ecocentric. Is it reasonable to suppose that nature is endowed by its own rights (intrinsic values) which should be respected by people? Or is it a question of humans alone and their place in the Earth ecosystem and in cosmos? It is substantial that people recognize in time which conditions are decisive for survival. It is then more effective to draw on the knowledge of scientists rather than on the consumer preferences. That is why expert values should be preferred against a standard consumer (laymen). Such expert valuations are able to reflect the intrinsic life-supporting functions of the environment.

The ecocentric approaches are not quite compatible with liberal neoclassical mainstream economics that is based on individualistic self-interested consumer valuations.

What is economics? Economics is a science on economic activities and about how people can or may decide on the use of scarce resources. The broadly used Economics textbook by P. Samuelson a W. Nordhaus (17th edition) presents the following definition:

"*Economics is the study of how societies choose to use scarce productive resources that have alternative uses, to produce commodities of various kinds, and to distribute them among different groups"*.

Let us add to this definition that not only productive resources should be understood under the term scarce resources, but primarily those environmental resources that maintain healthy living conditions.

By scarce resources economic theory understands production factors (land, labour, capital, energy) as production inputs. By land economics understands only those natural resources that are economically used, leaving aside all other nature and biodiversity, leaving aside the global Earth ecosystem. Current eclecticism of environmental economics (as derived from neoclassical background) consists in drawing its techniques from the fields of pure and applied economic theory; on the other hand, it has incorporated elements from the natural sciences, from system analysis, and from the domain of ethics. The resulting body of knowledge, however, is far from having achieved a synthesis of these components and no consensus has been reached regarding the way in which such a synthesis could be achieved.

At the same time, decisions on the environment are much more complex than decisions on private goods and services (characterised by divisibility, rivalry, excludability and depletability), e.g. bread, clothes, shelter/renting the flat, agricultural land, forest etc. Many environmental resources have the characteristics of public goods (non-divisibility, non-excludability, non-rivalry). A typical example of public goods are lighthouses or national defence systems, the Earth atmosphere, clean air and water, natural forests, climate regulation mechanisms and natural landscape ecosystems. With public goods, markets fail to allocate resources efficiently.

For most of human history, nature was used as a source of resources free of charge. In the last two centuries with the industrial revolution and especially in the last decades with the intensive economic growth and intensive pollution and destruction of nature in many parts of the world, nature and environment became scarce. Clean air and water, natural forests and natural landscape ecosystems are becoming scarce, scarcer than ever before.

Environmental economists are seeking to explain the principle that natural systems are multifunctional assets in the sense that the environment provides humans with a wide range of economically valuable functions and services (Turner, Pearce, Bateman, 1994, p. 17):

- a natural resource base (renewable and non-renewable resources),

- a set of natural resource goods (landscape and amenity resources),

- a waste assimilation capacity,

- a life support system.

Environmental and especially ecological economics apply the principles of scarcity and opportunity costs as well as principles of efficient allocation to the complete collection of natural and environmental resources. If these resources are becoming more scarce, then economics can play a role in devising the strategies to mitigate economic and environmental interests.

One of the main principles of sustainability is to find an equilibrium between direct consumption and use of nature and environment through economic activities (use of natural resources, sinks) on the one hand, and indirect use of nature as a life-supporting asset on the other hand (life-supporting, esthetical assets).

The question how market mechanism and free markets can help in looking for such equilibrium has been analysed by many authors.

Economic theory has already proved that a seller and a buyer are able to determine an acceptable market price provided the structural conditions of perfect competition are fulfilled. The institutional arrangements necessary for an efficient static allocation of resources in free market economy include the following (Perman, Ma, McGilvray, 1996, p. 90):

1) markets exist for all goods and services exchanged and are perfectly competitive,
2) all transactions have perfect information,
3) firms are profit maximizers, consumers maximize utility,
4) property rights are fully assigned,
5) no externalities exist,
6) all goods and services are private goods, there are no public goods and no common property resources,
7) long-run average costs are non-decreasing (if production were characterised by economies of scale, then natural monopolies would exist, and a competitive conditions could not be sustained).

An efficient static and intertemporal allocation would be sustained if these seven institutional circumstances were satisfied in all points now and in the future.

Beside public goods, **externalities** also complicate market allocations. An externality occurs when the production or consumption decisions of one agent affect the utility of another agent in an unintended way, and when no compensation is made by the producer of the external effect to the affected party. Negative externalities are endemic in modern market economies. Ayres and Kneese argued that it is not possible for these externalities to be internalised through unregulated market behaviour, and so in the absence of government intervention, inefficient outcomes are inevitable.

Many environmental resources are common property or open access resources. The combination of weak property regimes with externalities has led in market economies to the overuse and wasting of the stock of environmental resources (destruction of natural capital).

If the assimilation capacity of nature is limited, then the market mechanism necessarily contains certain externalities, as:

a) Clean productions are up-to-now exceptional;

b) Private property rights can hardly be applied on all environmental resources.

Due to the existence of externalities and public goods, market mechanism cannot be relied upon as an instrument that can assure the necessary quantity and quality of the environment and environmental goods and services. Economic systems are set up in such way that decisions are biased toward degradation.

For the solution of this market failure, economists recommend to evaluate external effects and public goods and to incorporate such values into economy (the evaluation and integration into economy must be guaranteed by the state and its democratic mechanisms). The valuation need not be and is not perfect, but any positive values are better than none.

Environmental valuations reveal human preferences, more generally benefits and costs. “Instruments” are then the mechanisms by which such valuations are transferred into economic system and economic decision-making of economic agents. Instruments are either administrative (command and control approach) or economic/market-based instruments (like emission payments, environmental taxes etc.).

4.2. The concepts of economic valuation and economic value

For the allocation of scarce resources, two main mechanisms are distinguished in democratic economic systems. First, a majority right to vote, where preferences of all participants are equal. Majority voting thus does not take into account the intensity of individual preferences. Therefore, a second system exists that respects individual preferences.

The concepts of economic valuation and economic value regard individual preferences as the basis of value. According to neoclassical theory, economic value derives from an **individual’s willingness to pay** (WTP) for some goods or service or for the exclusion of some costs (e.g. the exclusion of health risks from a polluted environment).

An alternative second approach stems from the **willingness to accept** (WTA) some compensation for a worse environment, for tolerating something people do not like. The second approach is based on the question how much an individual is willing to accept to keep his/her quality of life, in a worse environment, the same.

By looking at what people are WTP for a benefit and WTA to tolerate a cost, economists have found a way to measure the strength of individual preferences.

Until recently, economists supposed that both approaches should produce the same results. However, a substantial body of empirical evidence has recently been developed that provides a convincing evidence that the WTP and WTA measures are often quite different. Typically, the WTP measures turn out to be substantially lower than the WTA measures for the same policy change. Some authors argue that the economic measure of value depends upon a political judgement concerning the legitimacy of different reference points or endowments of property rights (Bromley, 1989).

The allocation of entitlements and claims to public goods can have dramatic effects on economists' estimates of value. To illustrate the nature of the problem that this disparity between the WTP and WTA measures poses for environmental policy analysts, suppose an environmental protection agency is called upon to conduct an economic analysis of a proposed air quality standard. An environmental economist finds that if an average individual believes he/she has **a right** to enjoy clean air and is asked how much compensation he/she is willing to accept to have the air quality remain the same (i.e., degraded), his annual WTA is US$300. On the other hand, if he/she is asked how much he/she is willing to pay to have the air quality standard promulgated (implemented), he/she may answer only $100 per year. In the latter case the implicit reference point is not clean air, but the existing degraded air quality. The WTP and WTA values depend on whether we assume that individuals have a right to clean air or industry has a right to pollute.

In market economies, the concept of economic value has traditionally been linked to valuing an individual's WTP to pay for some use value, for some benefit, obtained against price, or the WTA some compensation for a worse, more degraded environment. Economic value is derived from individual preferences, from the current generation.

The majority of environmental assets have their benefits and costs decisive in the long-term horizons that relate to future generations. The level of discount rates decide whether the needs of future generations are taken into account or not. The higher they are, the lower the respect for future generations' needs and the more difficult sustainable development.

Similar contrasts exist within one generation in the concept of WTP as the WTP is conditioned by the ability to pay, which means that it is conditioned by the income distribution in a society. As the willingness to pay of poorer people is lower than the WTP of richer ones, it means that in economic valuations based on WTP there is a contradiction that could be removed either by cutting off such income differences from the analysis, or directly in the economic system by a more equal income distribution through, for example, a better taxation.

In spite of the objections against the concept of economic value, economic theory (neoclassical mainstream theory, welfare theory) continues to define economic value as a summation of individual's willingness to pay. In connection with the environment, these are preference to pay for the quality of environment or for the exclusion of environmental damages. Economic valuation is, according to current economic theory, an anthropogenically subjectivistic procedure that expresses only preferences of individual consumers. It is thus a process that reveals a subjectively understood economic value.

This subjectively understood economic value can have, in relation to nature and environment, at least four main sources of value **(types of utilities)**.

Direct use value is the most common and most frequent source of economic value (according to neoclassical theory, an individual's utility from the use of goods is a source of value). In relation to nature, this means that economic value is derived directly from actual use of nature, i.e. from the use and extraction of natural and environmental resources. There are many forms of direct use values coming from direct nature consumption (breathing the air, use of water, nature use as a sink, use of forest benefits, nature beauties etc.) as inputs of economic activities (extraction of non-renewable resources, use of renewable ones), and ending with scientific forms of use of nature as a source of genetic information, in biotechnologies, in developing new medicines in the fight with cancer etc.

Indirect use value relates to primary ecological functions that nature and its ecosystems bring to human individual, to human species, to all living forms as a mother uterus of all life. Primary ecological functions come first of all from the ecosystem ability to conserve and develop itself and to resist the shocks and stresses that are attacking it. Healthy ecosystems can sustain ecological goods and services that are necessary for economic activities. These primary ecological values are absent in economic decisions in spite of the fact that they are decisive for the existence of production and, primarily, for the existence of life on Earth.

Option value is the third source of economic value, which also is not internalised by market. Option value flows from the uncertainty of future existence of ecosystem services. An amount that people are willing to pay for excluding such risk can be explained as an insurance that assures future access to such services.
There are at least two types of risk connected with biodiversity decrease. The less diverse ecosystems are, the higher the probability that they will be substituted by less useful ecosystems. This type of option value represents an insurance for keeping the future choice open (option). It is clear that the uncertainties in current biodiversity values and the irreversible character of biodiversity loss cause that such insurance payment is very high.

Second, the diversity of ecosystem can be substantial in cases of resistance to shocks and stresses. To avoid such risks, caused e.g. by climatic changes, society must ascribe to ecosystems and their biodiversity a special value in the form of payments for avoiding such risks.

Existence value is the fourth form of economic value that also is not commonly internalised by markets. Existence value follows from the conscious need of nature protection and life existence. xistence value expresses non-use value or passive value which brings no direct gain to the valuing person. Individual preferences may exist for maintaining resources even where no actual and future use is expected to be made of the resource. These preferences are the basis for existence value, unrelated to any use of valued resource. This form of value can be derived from different forms of altruism. People are willing to pay for maintaining tropical forests, or African elephant even if they do not expect any current and future direct use (direct visit of Africa).

Individual components of total economic value can be documented by the example of forest benefits (Pearce, in Layard, Glaister, 1994, p. 473):

Components of total economic value of forests

	Direct use values	**Indirect use values**	**Option values**	**Bequest values**	**Existence values**
Types of benefits	Timber	Biodiversity	Biodiversity	Biodiversity	Biodiversity
	Recreation	Watershed/ ecosyst. function	Recreation	Landscape	Landscape
	Biodiversity	Microclimate	Community integrity		
	Econ. security	Greenhouse impact	Landscape		
	Landscape	Community integrity			
	Forest fruits	Air pollution			
		Water pollution			

Economic security consisted in having supplies of basic raw material readily available, particularly at times when the probability of war was high. Its importance is now generally regarded as rather low. Community integrity benefits have their basis in the possibility that woodlands may support the maintenance of communities with cultures that are regarded as having an intrinsic worth, or that contribute to cultural diversity. In extreme cases, such as indigenous cultures in some areas of tropical forest, deforestation can eliminate an entire culture. The benefits labelled as microclimate, biodiversity, greenhouse impact, air pollution and water pollution all relate to the set woodland ecological functions.

Economic valuations are often confusing. Some authors talk about environmental valuations, others of nature valuations etc. Some value the changes in the state of human health and by means of this approach they talk about nature value. But what is really valued according to mainstream economics is not nature alone, but preferences of individuals in relation to changes of nature quality. Deriving economic value from only individuals' preferences comes from only demand side and omits the supply side (cost side). But economic value of nature must be derived from the comparison of both demand and supply side, from the comparison of nature gains and costs of nature restoration.

4.3. Economic valuation and sustainable development

It was already said that economists regard individual preferences as the basis of value, i.e. it is the present generation that is valuing. If a project is economically effective it need not be sustainable. This divergences can arise in the case of non-renewable resources, where any positive rate of extraction leads to their depletion. In this case present generation exhausts the resources on the account of future generations.

In present conditions of growing global environmental changes the term of capital should incorporate three main items:

1. man-made capital,
2. critically threatened natural capital,
3. other natural capital.

Man-made capital, as a sum of physical capital (plant, equipment, buildings and infrastructure, accumulated by devoting part of current production to investment purposes) and human and intellectual capital (stocks of learned skills, stocks of disembodied useful knowledge) can be arbitrarily increased according to human needs and wants.

Critically threatened natural capital (ozone layer, global climate, biodiversity, global Earth ecosystem, regional ecosystems etc.) is composed of those important parts of the Earth that create basic conditions for existence of life and in that sense cannot be substituted by man-made capital. This capital is irreplaceable and its value is infinite (or it stands above the value system) and its protection should create absolute limiting condition of any human activities. It means to set the limits of air and water quality, critical loads, normatives for biodiversity etc. and on intervening economic activities to internalise all existing externalities. Global biosphere is composed of local and regional ecosystems. These non-market parts of nature should be valued.

The third group is other natural capital that comprises renewable and non-renewable natural resources. These resources should be more completely valued, not only as production factors but also as environmental resources. Their values should be fully internalised in related economic activities. Renewable resources should be used in a way that is sustainable (harvests should not be higher than natural rate of reproduction). Non-renewable resources will be exhausted even if the rate of extraction is very low. Environmental economics has only general prescriptions for their use, like improving their use effectiveness, substitution by renewable resources etc.

This capital distribution has multilateral impacts on the valuation of human activities:

1. it is gradually necessary to avoid damages on critically threatened natural capital and in accordance with precautionary principle to assess human activities from the viewpoint of irreversible impacts on environment and its environmental goods (natural ecosystems);

2. within other natural capital and man-made capital it is necessary to internalize all negative externalities in human activities and by this to assure that the total level of capital will not decrease;

3. on macroeconomic level to incorporate into national accounting real consumption of natural capital (by analogy with depreciation of physical capital). Many environmental services are not reflected in national accounting, although if they are destroyed society must carry high costs of environmental protection that are incorporated into the growth of national product.

In relation to environmental capital it is important to implement prices of damaging that capital. Price implementation should be viewed also as defining or re-defining of property rights. If such property rights are established, then by proper prices should be understood prices on the level marginal social costs for keeping the quality of environment.

Recent research results show that the total value of world ecosystem services is infinite and that also their marginal value (value of substituting present environmental services) is very high and achieves annually double or treble of the annual world GDP (Costanza et al., 1997).

To integrate environment and economy means to reformulate the paradigm of neoclassical economics, move it from the individualistic homo economicus to a social man in society and, last but not least, to move it to public decision-making with respect to public preferences (public needs) which are not simply a sum of preferences of independent individuals. To integrate environment and economy also means to broaden an individualistic concept of economic value by socioeconomic values and to find relevant methods for revealing and calculating them.

For classical economists who were obsessed with the labour theory of value, nature was a source of use values, but due to its abundance only a limited source of exchange values. Nevertheless, they arrived at the conclusion that ***commodities derive*** *their exchangeable* ***value from*** *two sources: from their* ***scarcity, and from the quantity of labour required to obtain them*** (D. Ricardo, 1910). **The neoclassical notion of economic value made a backward step to the unilateral concept, based only on the demand side (human preferences), where only self-interested preferences pay**. That is why pioneers of the contingent valuation (CV) method are finally recommending to exclude nonuse damages based on CV from natural resource damage assessment liability (Desvousges, 1995).

The main ethical challenge for the subjectivist neoclassical concept of economic value, ensuing mainly from growing environmental problems, consists in the fact that while the neoclassical framework comprises only subjectivistic self-interested value (unless consumers express a preference for certain environmenal attributes or objects, those attributes have no intrinsic value), then environmental and, mainly, ecological economists also include the objectivistic concept of intrinsic value into the total economic value as it is irreplaceable for sustainable life.

Such intrinsic values cannot be assigned by means of a subjectivistic concept of economic value (human preference to the existence of things, independent of their instrumental services), but they should be incorporated into the economic framework by means of expert evaluations (but only those values which are accepted by a democratic majority). Such evaluations should be based on a combination of costs needed for revitalizing damaged ecosystems and sustaining constant natural assets, and expert evaluations of environmental benefits for human society.

4.4. The basic methods of imputing values for non-market environmental goods and services

The majority of environmental problems arise due to market economy failure in valuing nature and its environmental resources. They fail in valuing the quality of environment. Ecological impacts of human decisions and activities have neither been expressed in economic calculations of individuals nor in evaluation of public projects. The consequences are that too many human activities have freely caused environmental damages (damages on human and ecosystem health) and, *vice versa,* too little economic activities brought positive ecological gains.

The basic goal of valuing non-market environmental goods and services is to reveal:

- either the total economic value of some stock of natural capital (expressed as a sum of discounted flows of environmental services or as a sum of expert values of biotopes, habitats and their areas),
- or the economic value of the change in this stock of natural capital (change in the quality of environment) which is expressed in the change of discounted flows of environmental services or in the change of the stock of biotopes.

In mainstream economics, economic values are traditionally derived from the utilitarian basis coming from the concept of willingness to pay (WTP) for satisfying the preferences (wants and/or needs) of an individual consumer. Even among ecological economists, the term "value" is defined from the utilitarian (user) point of view. For example, Farber, Costanza and Wilson (2002, p. 375) define "value" as "to mean the contribution of an action or object to user-specified goals, objectives or conditions. A specific value of that action or object is tightly coupled with a user's value system because the latter determines the relative importance of an action or object to others within the perceived world". On the other hand, Turner, Pearce and Bateman (1994) show the limits of such individualistic utilitarian environment valuation, noting that "economic valuation measures human preferences for or against changes in the state of environments. It does not value the environment" (p. 38).

The utilitarian approach has been used since the mid 19th century for valuing the natural resource services (e.g. Faustmann, 1849). Natural resources have been valued, as production factors and assets, through their market services in economic activities (production, exchange and consumption) as the sum of the future net benefits (rents) discounted to present value in finite or infinite time horizons (for non-renewable and renewable natural resources).

Since the 1870s, the utilitarian paradigm has been supplemented by the neoclassical concept of marginal valuation. The value of goods has been derived from its marginal utility for the user. The total value of a commodity is given by the number of commodity units produced (supplied) multiplied by the marginal utility from the last unit consumed (demanded).

The general expression for the value of an asset, V, in the base year, 0, is simply the sum of the net economic benefits it yields in each year *t*, over the lifetime, *T*, of the asset, discounted to present value by the discount rate, *i*.

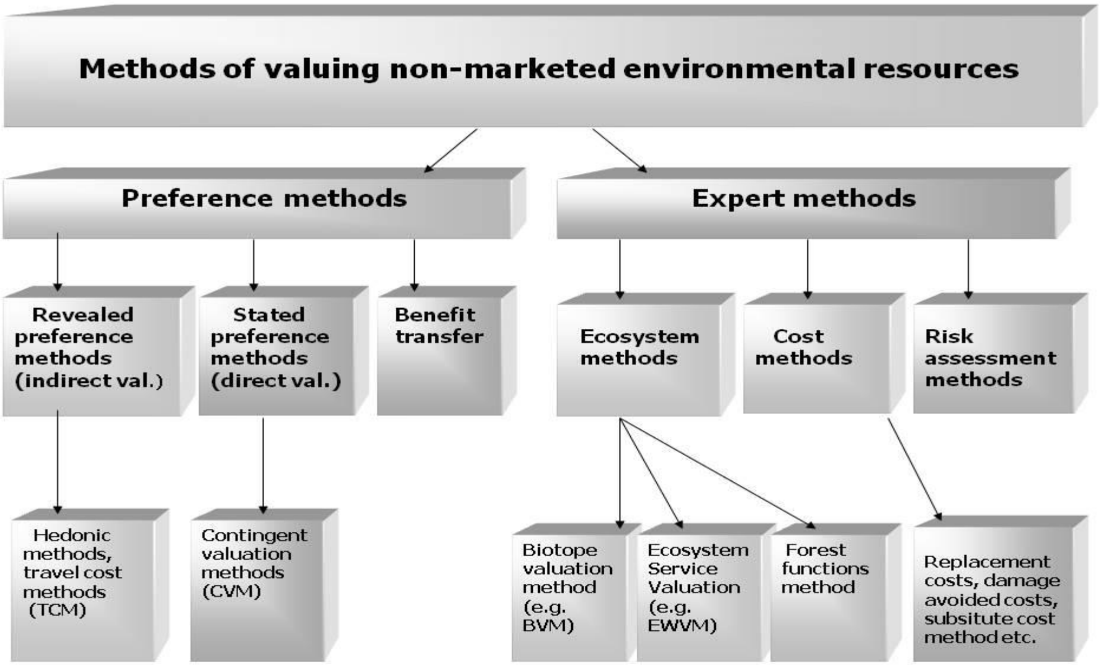
$$V_o = \sum_{t=0}^{T} \frac{r_t Q_t}{(1+i)^t} \qquad (1)$$

where *r* is the unit rent calculated as revenue minus the marginal cost of harvesting, and *Q* is the total harvest in a given period (Lange, 2004, p. 74).

Environmental valuations are in principle in the main two forms. They are either valuation of environmental assets (valuation of environmental resource stock) or valuations of changes in these environmental assets (stocks). Valuation of environmental resource services that can be found most often in environmental literature is the valuation of the flows of services, i.e. the valuation of changes in the stock of environmental resources. In the valuation of damages on environment there are valued damages on quantity and quality of environmental services.

There are two basic approaches and methods for the valuation of non-market environmental resources (see e.g. Turner, Pearce, Bateman, 1994, p. 115):

1. **those which value a commodity via a demand curve:** these are based on the either stated (direct methods) or revealed (indirect methods) preferences of willingness to pay or willingness to accept (**preferential methods**);
2. **those which do not:** these are nevertheless useful heuristic tools in any cost-benefit appraisal of projects, policies or courses of action. Non-demand curve approaches comprise dose-response methods, replacement costs, mitigation behaviour, opportunity costs and newly also expert valuations of biotopes (habitats). Methods for valuing non-market environmental goods and services (Fig .4.1)



Within the preference methods, two main approaches can be identified in current environmental literature (see e.g. OECD 1994):

1. the first method is based on **already revealed preferences** on related markets, economists try to find goods or a service that is sold in markets and is related to or “bundled with” the non-market service, the comprise hedonic property value method, hedonic wage model, travel cost method and avertive behaviour method;
2. the second method is based on a direct revealing of preferences. People are asked how much they are willing to pay to have a specified environmental quality happen. This is known as “stated preferences” or “contingent valuation method” (CVM).

Let us note that both these preference approaches draw on the individualistic concept of value; they draw on the demand side of the valuated problem.

The first approach may be called a ***method of revealed preferences*** or a method of “***related markets***”. These are the methods of indirect valuation through the behaviour of people on related markets. The estimates are based on what people actually did and why they did it – not what people said they would do under a set of hypothetical conditions. These methods are sometimes called indirect methods because they value on the basis of indirect behaviour. They contain the ***method of hedonic pricing***, where the environmental value is derived from the differences of property values in different locations (with different environmental quality). Some other methods, like the hedonic wage model, travel cost method and avertive behaviour method, will be described further. These methods are connected with accepting a set of assumptions that remains largely untested. Being derived from the real behaviour on markets, these methods reveal only direct use value.

The second approach consists in a **direct asking of people** about what they are willing to pay (stated preferences/CVM). Word contingent is here a synonym of conditional. These methods are most frequently used in practice and will be described futher in more details. The main problem of these methods is their hypothetical character, they answer on **only a hypothetical willingness to pay**. Sometimes these methods are called direct methods as people are directly asked to reveal their preferences.

If people were able to understand clearly the change in environmental quality being offered and answered truthfully, this direct approach would be ideal. The central problem is whether the intentions people indicate ex-ante (before the change) will accurately describe their behaviour ex-post (after the change) when people face no penalty or cost associated with a discrepancy between the two. There are also objections against these methods as they are strongly conditioned by income differences.

Environmental valution methods contain also an *experiment.* If an analyst wanted to know how much people value a potential new national park, the park could be created and an entrance fee could be charged. An analyst could then observe how many people *actually* used the park, in effect exchanging money for the recreation and the aesthetic experience of visiting the park. In practice, such large scale experiments are expensive and politically impossible to implement.

The methods based on costs or risks are focused on valuing the changes in the flows of environmental services or on environmental damages. The concept of damage requires to set some reference point of quality. The usage of different cost categories (restoration costs, replacement costs, alternative costs etc.) are proxy for the benefits of reaching the standard. Non-preference methods include also a dose-response method. The dose-response approach requires the existence of data linking a human, plant or animal physiological response to pollution stress (loss of crop output from air pollution). For situations involving human health, complex questions relating to the value of human life have to be addressed (analysts seek to value the increased risk of illness or death).

4.4.1. Methods of surrogate, related markets (indirect methods)

These methods, called also indirect methods, derive environmental values from the behaviour of people on related markets. Related markets are those markets that have environmental aspects as one aspect of use value. A typical example are apartment (housing) markets where environmental quality is one aspect of property use value. Other methods include hedonic wage model, travel cost method and avertive behaviour method.

The method of hedonic pricing

This method (see Griliches, 1971, for the origins) comes from the assumption that property market price is dependent on its use values. The hedonic pricing method (HPM) has been used extensively in developed countries to place values on environmental benefits and costs relevant to air and noise pollution. Given that different locations of property will have different levels of environmental attributes and that these attributes affect the stream of benefits from the property, then the variation in attributes will result in differences in property values (since property values are derived from the stream of benefits). The HPM looks for any systematic differences in property values between locations and tries to separate out the effect of environmental quality on these values.

The HPM involves the following steps:

- Defining the market commodity (in this case property) and the environmental goods or service of concern which is an attribute of the market commodity (e.g. air pollution).
- Specifying the functional relationship between the market price and all the relevant attributes of the market commodity (structural characteristics of housing, neighbourhood characteristics, environmental quality aspects). This is called Hedonic Price function.
- Cross-sectional (covering a large number of similar properties at one point in time) or time series data (covering a smaller number of similar properties over a number of years) are collected (e.g. from real estate agents).
- The coefficient on environmental quality $\Delta P/\Delta E$ is calculated using techniques such as multiple regression analysis. Such coefficient is known as the marginal implicit price of environmental quality and gives the additional amount of money that must be paid by an individual to move to an identical property with a higher environmental level. The shape of demand curve is estimated from available discrete data.

The HPM has been widely and effectively used to estimate the impacts of environmental factors on property values. The approach does not measure non-use values and is confined to cases where property owners are aware of environmental factors and act because of them. The method is not very suitable where markets are not functioning efficiently (e.g. where prices or rents are under government control). For this reason the impact of noise on the rent level was not proved in Germany (see Borjans, 1983).

Another variant of the HPM is the wage risk method which is used to place a value on the benefits of environmental improvement to human health. These improvements will consist of reduced mortality and morbidity. Benefit estimation requires that we place a monetary value on the benefits of changes in the risk of death, injury and illness. It is assumed that an individual can substitute between income and health (they can make trade-offs between income and health) with the trade-off measured by WTP. Market now being looked at is not property but the labour market. Cummings, Schulze and Mehr (1978) estimated hedonic wage function for different towns, where among independent variables the differences in town infrastrucuture were included.

The wage risk method involves the following steps:

- Defining the labour market commodity (in this case job and wage) and the environmental goods or service of concern which is an attribute of the market commodity (e.g. risk of an accident).
- Specifying the functional relationship between the market price (wage) and all the relevant attributes of the market commodity (job related characteristics, socioeconomic characteristics of the individual, accident - death or injury – risk for the job). This is called an earnings function.

- Cross-sectional data for wage rates and the other associated characteristics are collected (e.g. from Standard Class Industry Codes).
- Multiple regression analysis is used to calculate the coefficient on accident risk, i.e., $\Delta W/\Delta R$. Such coefficient is known as the marginal implicit value of the risk of an accident and gives the additional amount of money that must be paid to an individual to move to an identical job with a higher risk of death or injury level. The shape of earning curve is estimated from available discrete data.

The coefficient on the risk term gives the amount €X per year that must be paid to a worker to accept a job with an extra 1 in 100,000 chance of an accident occurring. For a group of 100,000 workers each with an increase of 1 in 100,000 in the risk of an accident, there would statistically be one extra death on average. €X was paid to each of the 100,000 workers to accept the statistical death of one person and so the Value of this Statistical Life is €100,000.X

So, Value of Life = 100,000 . $\Delta W/\Delta R$.

The Travel Cost Method

The Travel Cost method (TCM) has been widely used to measure the demand and benefits of recreation site facilities and characteristics as well as for the general valuation of time (OECD, 1994).

The basic idea behind the method is that information on money and time spent by people in getting to a site is used to estimate the WTP for a site facilities or characteristics. The problem here is that some recreation sites charge a zero or negligible price which means that it is not possible to estimate demand in the usual way. However, by looking at how different people respond to differences in money travel cost we can infer how they respond to changes in entry price, since one acts as a surrogate price for the other.

The travel cost demand function is interpreted as the derived demand for a site services and depends on the ability of a site to provide the recreation activity. Only use values are therefore considered, with existence and option values being ignored.

The procedural steps involved in the TCM are as follows:

1. For the site in question, the area around is divided into concentric circles (called zones), such that the travel cost of getting to the site and back from each zone is measurable. The travel cost includes any site entrance fee, the direct money costs of getting there (petrol, etc.), as well as time costs involved in getting to the site and at the site.
2. Visitors to the site are sampled using a questionnaire to determine their: zone of origin and other demographic/attitudinal information, frequency of visits to the site in question, frequency of visits to substitute sites, trip information, e.g. length of trip, nights stayed in motel etc., travel paths, meals at restaurants, etc.
3. Visitation rates are then found for each zone of origin using the above information (to get visitor days per capita). A measure of travel costs to and from the site is found using the above information.

4. Statistical techniques such as multiple regression analysis are used to test the hypothesis that visitation rates depend on travel costs, i.e. visitation rates are regressed on travel costs and other socioeconomic variables such as income, education, etc. as well as the prices and distances of competing sites e.g., $V_i = a + b.TC_i + c.INC_i + d.ED_i + \ldots + f.STC_i$ where V is the number of visits to the site, TC is the total travel cost to the site, INC is the individual's income, ED is their education, STC is total travel cost to substitute sites, the subscript i denotes the respondent, and a,b,c,d,f, are the coefficients to be estimated. The coefficient b gives the change in number of visits for a change in travel cost (admission price).
5. The observed total visitation for the site from all zones represents one point on the demand curve for the site.
6. Assuming that any increase in travel cost has the same effect on visitation as an equivalent increase of a hypothetical admission fee, then other points on the demand curve are found by using the estimated visitation rate equation to compute visitation rates and total visits for all travel cost zones for a given increase in admission price (or rather its surrogate, travel cost). This is repeated for successive increases in admission price such that the full demand curve is found. The benefits (consumer surplus) of the site are then found from the area under the demand curve.

Since the cost of visiting a site consists of the transportation costs plus the costs of the time taken to get to the site and the time spent at the site, the role of time is critical to the estimation of travel costs. Time has an opportunity cost, i.e. there is some alternative usage of that time available; for example, one could work instead. From previous empirical works it can be estimated that the shadow price of time lies at about 1/3 of the wage rate (Cesario, 1976).

The TCM is an important method of evaluating the demand for recreational facilities. Nevertheless, there are reservations as to its use, particularly concerning the large amounts of data required which are expensive to collect and process. The method works best when applied to the valuation of a single site, value is non-transferable to other site valuations. Some TCM reviewing studies were published, e.g. Smith and Kaoru (1990) analyse 200 TCM studies from the period 1970-1986. Walsh, Johnson and McKean (1992) carried out broader analysis based on 156 TCM estimations, 129 CVM and 2 HPM in period 1968-1988. The mean value of a recreation day was $34 and the median is $27. The highest values are reported for hunting, fishing, boating, hiking and winter sports.

The TCM is limited by expressing only direct use values and cannot be used to reveal option, bequest or existence values. It is a very utilitarian approach that can contradict with nature conservation goals.

4.4.2. Contingent valuation method (CVM)

The application of CVM means a preparation and use of a specially structured questionnaire in which respondents (individuals or households) are asked a series of questions revealing their preferences for a specific change in environmental quality. The method is termed “contingent” because environmental quality change is not, in fact, necessarily going to be provided by the research analyst: the situation a respondent is asked to value is hypothetical. Due to this hypothetical character CVM can be applied universally to obtain values of private, semi-public or purely public goods and sevices. CVM is used especially for valuing environmental goods and services for which a conventional market does not exist.

At first glance CVM appears similar to public opinion polling and market research techniques. Although there are similarities, there are also significant differences. CVM seeks to obtain monetary value of the change in well-being an individual (or household) would obtain from the change of environmental quality. Public opinion polls are not concerned with monetary valuations. Market researchers want to know whether people will purchase some private goods while CVM typically focuses on individuals' preferences for non-market public goods.

Types of CVM interviews

The CVM interviews can be conducted by mail, telephone, or in-person or some combination of these. In-person interviews are generally considered to provide the highest quality data if surveyors are properly trained and familiar in details with the valued problem. The major disadvantages are their expensiveness and possible bias from asking the same question in different ways.

In countries with extensive telephone network, telephone interviews offer several advantages. They are relatively inexpensive and random-digit dialling methods can be used to obtain a relatively representative sample of respondents. The interview is interactive but without the possibility of using pictures and graphical explanations.

Mail surveys have often been successfully used as well, especially if respondents were compensated for completing the questionnaire. All three forms can also be combined.

Content of questionnaire

Most CV survey instruments (questionnaires) should contain three main parts:

First, to explain the environmental problem valued, careful description of the valued problem, often with the use of pictures and diagrams, to explain how the problem is related to the respondent and in which way he/she would pay, institutions responsible. Problem description should include information on such things as: when the environmental quality change will be available, how the respondent will be expected to pay for it, how much others will be expected to pay, what institutions will be responsible for the change etc. Problem description must be sufficient, but short enough.

Second, the respondent is asked one or more questions how much he/she is willing to pay for the improvement of environmental quality (to accept for environmental quality loss).

Unique to the CVM are the description of hypothetical market and the valuation questions. There are several ways that a respondent can indicate his/her choice or preferences. One is to answer a question as to whether or not he would want to purchase the service if it cost a specified amount. We refer to this as a **YES/NO question**. Another possibility is to ask a direct question about the most he/she would be willing to pay for the goods or service, we refer to this as a **direct or open-ended question**. YES/NO questions are generally preferred and respondents may be shown a list of possible answers in the form of a "payment" card.

The respondent must be put into a position of the buyer, must be informed that he/she has no right for the public goods without paing for it. As public goods generally have the characteristics of joint consumption and non-exclusion, the respondent must be informed how his/her answer will influence the project implementation (to avoid his/her free-rider behaviour).

Environmental problems are the main area of CVM applications (see e.g. Braden et Kolstad, 1991; Cummings, Brookshire et Schulze, 1986 etc.), especially in cases where no other methods can be used. CVM is able to reveal not only use values, but also optional and existence values. As showed by Greenley, Walsh et Young (1981), these non-use values can reach half of the total value.

Third, CV survey usually includes a series of questions about the socioeconomic and demographic characteristics of the respondent and his/her family.

Types of errors and biases in CV surveys

Although CVM is nearly universally applicable and can value all components of economic value, revealing preferences through questions is connected with many problems. There are three basic categories of errors: on respondent side, on surveyor side (miscommunication between surveyor and respondent), errors with aggregation of individual responses.

Respondents may not reveal their true value of the goods or service:

- strategic biases: respondents can understate their true preferences for public goods in hopes of a “free ride” while others pay; if the price for public goods is not tied to an individual’s WTP response, but the public goods provision is, respondents may over-report their true WTP to ensure the provision of the goods;
- biases are given by specific procedures (how questions are asked, by the way of payment, information given etc.).

The second cause of biases consists in the fact that CV researcher may not have specified the most policy-relevant hypothetical scenario for the respondent to value. People may be willing to pay for improved environmental goods and services but only hardly can distribute such hypothetical WTP into the individual environmental fields and media.

The third group of errors can be generated by sampling errors (non-random samples, non-responses) and by insufficient sample size.

In public goods provision, biases cannot be excluded, but many authors believe that biases are not fundamental. Approaches are seeked to exclude overstating the real WTP (Hoehn et Randall, 1987). Fundamental for good results is a quality of the questionnaire and its proper application.

Experience from practical CVM applications proves that a properly prepared and carried out survey can bring results as reliable as in other methods (see e.g. Mitchell and Carson, 1989).

On the negative side, some naive analysts are attracted to the CVM because it appears on the surface to be so easy to do: just ask people a few questions and tabulate their answers. But the art of asking questions” is fundamental for obtaining reliable results.

That is why in the following part some basic assumptions for successful CVM results are presented.

Analysis of WTP responses

Before the analyses can be undertaken, the data must be cleaned by removing "protest responses" given by individuals who for one reason or another reject the hypothetical scenario and refuse to give meaningful answers. Protest bids can be either zero bids or very high bids, depending on the context of the valuation question. Analyst must remove protest bids from the data set because this information will bias the conclusions about the sample respondents' WTP. Of course, not all zero or very high bids can be considered protest bids (they are related to income or some other socioeconomic characteristics), the appropriate treatment requires skill.

Information obtained from CV surveys is analyzed in three, increasingly sophisticated ways. First, analysts examine the frequency distribution of the responses to the valuation questions. Second, analysts look at cross-tabulations between WTP responses and such variables as socioeconomic characteristics of the respondent and attitudes toward the environment. Third, analysts use multivariate statistical techniques to estimate a valuation function that relates the respondent's answer to the socioeconomic characteristics of the respondent and attitudes toward the environment. The purpose is to see whether the respondent's answers are consistent with theory and common sense and to establish statistical relationships.

In summary, to obtain reliable results from CV surveys, many assumptions must be fulfilled. American economist K. Arrow et al. presented guidelines for conducting CV studies. Let us mention some of them.

Guidelines for conducting CV studies (Arrow K. et al., 1993)

<u>General guidelines</u>

1. <u>Sample Type and Size</u>: Probability sampling is essential. The choice of sample specific design and size is a difficult, technical question that requires the guidance of a professional sampling statistician.
2. <u>Minimize Non-responses</u>: High nonresponse rates would make CV survey results unreliable.
3. <u>Personal Interview</u>: It is unlikely that reliable estimates of values can be elicited with mail surveys. Face-to-face interviews are usually preferable, although telephone interviews have some advantages in terms of cost and centralized supervision.
4. <u>Pretesting for Interviewer Effects</u>: An important respect in which CV surveys differ from actual referendum is the presence of an interviewer (except in the case of mail surveys). It is possible that interviewers contribute to "social desirability" bias, since preserving the environment is widely viewed as something positive. In order to test this possibility, major CV studies should incorporate experiments that assess interviewer effects.
5. <u>Reporting</u>: Every report of a CV study should make clear the definition of the population sampled, the sampling frame used, the sample size, the overall sample non-response rate and its components (e.g., refusals), and item non-response on all important questions. The report should also reproduce the exact wording and sequence of the questionnaire and of other communications to respondents (e.g.,

advance letters). All data from the study should be archived and made available to interested parties.

6. Careful Pretesting of a CV questionnaire: Respondents in a CV survey are ordinarily presented with a good deal of new and often technical information, well beyond what is typical in most surveys. This requires very careful pilot work and pretesting, plus evidence from the final survey that respondents understood and accepted the description of the goods or service offered and the questioning reasonably well.

Guidelines for Value Elicitation Surveys

7. Conservative design: When aspects of the survey design and the analysis of the responses are ambiguous, the option that tends to underestimate willingness to pay is generally preferred. A conservative design increases the reliability of the estimate by eliminating extreme responses that can enlarge estimated values wildly and implausibly.
8. Elicitation Format: The willingness-to-pay format should be used instead of compensation required because the former is the conservative choice.
9. Referendum Format: The valuation question generally should be posed as a vote on a referendum.
10. Accurate Description of the Program or Policy: Adequate information must be provided to respondents about environmental program that is offered.
11. Pretesting of Photographs: The effects of photographs on subjects must be carefully explored.
12. Reminder of Substitute Commodities: Respondents must be reminded of substitute commodities. This reminder should be introduced forcefully and directly prior to the main valuation to assure that the respondents have the alternatives clearly in mind.
13. Temporal Averaging: Time dependent measurement noise should be reduced by averaging across independently drawn samples taken at different points in time. A clear and substantial time trend in the responses would cast doubt on the "reliability" of the value information obtained from a CV survey.
14. "No-answer" Option: A "non-answer" option should be explicitly allowed in the addition to the "yes" and "no" vote options on the main valuation (referendum) question. Respondents who choose the "no-answer" option should be asked to explain their choice.
15. Yes/No Follows-ups: Yes and no responses should be followed up by the open-ended question: "Why did you vote yes/no?"
16. Cross-tabulations: The survey should include a variety of other questions that help interpret the responses to the primary valuation question. The final report should include summaries of willingness to pay broken down by these categories (e.g., income, education, attitudes toward the environment).
17. Checks on Understanding and Acceptance: The survey instrument should not be so complex that it poses tasks that are beyond the ability or interest level of many participants.

In summary we can say that obtaining reliable results from a CV survey is a difficult task, which is proved by the above mentioned long list of guidelines.

Critics of the CVM believe that the probability that unreliable results will be obtained is high and that CV studies are never worth doing.

From our perspective CVM is an important, often useful approach to measuring individuals' WTP for goods and services that are difficult to value with other approaches. CVM is especially useful in solving politically complicated environmental quality problems where there are very different opinions of different stakeholder groups.

4.4.3. Methods of valuing environmental goods and services through non-demand curve approaches (through costs and damages)

Method of abatement costs (avertive expenditures), mitigation behaviour: This method comes from the costs necessary for prevention, for abating the pollution of environment. These are costs for complying with emission limits for different polluting matters ($SO2$, NOx, dust etc.). These costs can serve as surrogate for environmental benefits (if these are unknown and very difficult to measure).

Method of replacement or restoration costs: The costs of replacing or restoring a damaged asset. Uses these costs as a measure of the benefits of restoration, costs are proxy for the benefits of reaching the standards. Replacement costs of a wetland could be wetland restoration elsewhere in a region, wetland relocation, or new wetland creation and might be allowable as a first approximation of future wetland conservation or wetland loss. Restoring costs can be taken as a minimum valuation of the damage done.

In the **opportunity cost method** no direct attempt is made to value environmental benefits. Instead, the benefits of the activity causing environmental degradation – say, drainage of a wetland to allow intensive agriculture – are estimated in order to set a benchmark for what the environmental benefits would have to be for the development (agriculture) *not* to be worthwhile. While this is not a valuation technique, it has proved to be a very useful aid to decision-makers, e.g., much of the recent loss of wetlands in Europe due to the operation of the Common Agricultural Policy represents a socially inefficient result because of the heavily subsidized nature of the drainage investments and arable crops that replaced the wetland. Such conversions have now all but ceased as subsidies have been withdrawn or lowered (Turner, Pearce, Bateman, 1994).

Methods of risk valuation (dose-response method): The dose-response procedure does not attempt to measure preferences, it values an increase in pollution level. In the first step, estimates are obtained of the consequences (the response) of the pollution "dose". These estimates are in natural physical units for the medium being affected (such as mass of timber damage, loss of agricultural output, physical damage to buildings, wildlife losses from acidification) and for human health damage. A relationship among the change in environmental pollution and the increment in damages is identified. Physical damages are transferred into monetary terms by either market prices (e.g., loss of agricultural commodities), through some costs (e.g. cost of health care – cost of compensation, or cost of prevention in case of emission reductions) or by some imputation method.

This method involves the following steps:

1. estimate a physical damage function R=R(P, other variables), where R is physical damage (response) and P is the cause of the damage (dose).
2. calculate the coefficient of R on P, i.e. $\Delta R/\Delta P$, using statistical methods such as multiple regression analysis
3. calculate the actual change in pollution due to environmental policy change, i.e. ΔP.
4. calculate $V.\ \Delta P\ .\ (\Delta R/\Delta P)=V.\ \Delta R=\Delta D$, where $=\Delta D$ is "damage avoided". The response to the actual change in pollution (ΔR) is found and is multiplied by the monetary value per unit of physical damage (V) to give the "damage avoided" or benefit of the environmental effect.

This method has been used mainly in the USA, where the relations among pollution changes and their impacts on human health or ecosystems were identified. The damage function approach is used extensively where dose-response relationships between some cause of damage such as pollution and output/impacts are known (effects of pollution on health, physical depreciation of material assets). It is used where people are unaware of the effects that pollution causes or direct methods are impossible due to a lack of data. On the other hand, this method is not convenient for applications where there are the non-use values important and relatively high.

If some dose-response estimates exist, then it is relatively easy and cheap to apply them in other cases. Such a case study was project Silesia, in Ostrava agglomeration the results of U.S. EPA were applied for measuring the risk of death due to emissions from metallurgy and coke production.

Similarly as in the case of natural resource valuation, the non-market environmental assets started to be valued, within utilitarian tradition, since the late 1960s and early 1970s by identifying individuals' willingness to pay for their non-market environmental functions and services. A number of imputation methods has been developed that estimate total economic value by revealing the preferences held by human individuals (Moran, Bann 2000, Farber et al. 2002, Turner et al. 2003). Within the utilitarian paradigm, the concept of total economic value does not encompass any value that intrinsically resides in environmental assets (Turner, Pearce, Bateman 1994, p. 109).

The total value of natural or environmental assets is estimated through their market services in economic activities (production, exchange and consumption) or their non-market services as a sum of the future net benefits (rents) discounted to present value in finite or infinite time horizons (for non-renewable and renewable natural resources). Linking the valuation with the category of services binds the valuation into the utilitarian framework, in which the level of service depends on actual social demand for such a service.

If in market economies the value of natural and environmental resources is estimated as a flow of goods and services in time, i.e. as a discounted sum of future net benefits over the period of their utilization (Sejak et al., 1999), then, in the case of non-marketed environmental goods, such an approach is impractical from the following reasons:

- It is impossible to enumerate all of the environment's non-market services for humans, because we currently know only a fraction of the relations and regularities in ecosystems' functioning (as proved for example by the unsuccessful Biosphere 2 experiment). Above, if ecosystem services are irreplaceable in their life-supporting role, then their total monetary value is infinite.

- The number of ecosystems services is similarly unlimited, so the total economic value of world ecosystems as a life supporting part of nature is infinite.
- The necessity of using some discount rate opens disunited opinions on the level of such a rate that ranges from several percentages to even negative values.
- In multi-criteria analyses one can hardly add the benefits for nature that contradict the benefits for human individuals.
- To value services for human individuals is a restrictive process, because the primary benefits inside the ecosystems are more important.

Due to the above mentioned limits, measuring individual ecosystem services generally leads up a blind alley. For decision-making authorities we should try to estimate not individual services, but total ecosystem potential of biotopes as specific environment for specific living plant and animal species. The fundamental aim in non-market valuations of nature is not revealing absolute values of ecosystems (as assets) and their services flows but to express the effect of a marginal change in biotopes as specific environment (specific territory) for specific ecosystems. For political decision-making reasons we should primarily value an ecological potential of respective territory and compare it with potential or real economic benefits from development projects.

From the overview of valuation techniques it can be seen that they are based either on stated or on revealed preferences of individual consumers. As Turner et al. (2003, p. 494) show, what is at issue here is whether it is meaningful to say that individuals can assign a quantified value to nature or its component parts, reflecting what they consider to be intrinsic value. At the same time, consumers that mostly are not specialists on ecosystem functioning can hardly set proper preferences for ecological interrelations existing in ecosystems. Ordinary people (laymen) can hardly know anything about carbon sequestration, fixing of nitrogen, hydrological cycles, biodiversity, production of oxygen, sustaining global or regional climate, soil generation etc, although these are irreplaceable life-supporting services. Normal people do not incorporate these values among their use or non-use values, they have no preferences for them.

Above, the sum of such individual preferences may even substantially differ from the social preferences to environmental quality that are generated within parliamentary and governmental decision-making activities. In representative democracies, the government and parliament are those who primarily take decisions in the field of environmental protection.

The space for applying preferential valuation methods is thus rather narrow and is limited in individual specific case studies where there is conflict of economic and environmental interests. CVM is generally counted by many scientists (e.g. J.R. Kahn, S. Stewart, R. O’Neill, 1999) as inadequate for biodiversity valuations.

Expert ecosystem methods are based not on individual consumer preferences but on the knowledge of interdisciplinary teams of scientists who value environmental functions of biotopes. Results of their valuations can be incorporated into economic framework by political decision-making processes. Expert methods are preferred in Europe, because experts (scientists, researchers) have relatively most complete knowledge on ecosystem functions and their internal relations.

Among ecosystem methods belongs e.g. a method prepared by experts from the Center for Environmental Sciences D.M. King a L.A. Wainger "*Assessing the Economic Value of Biodiversity Using Indicators of Site Conditions and Landscape Context*". This method evaluates any service of an ecosystem by seven characteristics: 1) service level, 2) service scarcity, 3) service substitutability, 4) number of people with access to service, 5) costs of obtaining and sustaining the access to service, 6) preferences for service and 7) risk of interrupting the flow of service. In the Czech Republic, ecosystem methods include the method of valuing the functions of forests developed by Prof. Vyskot et al. at Mendel University in Brno and the Hessian method developed by authors in the Czech Environmental Institute.

4.5. Valuation of biotopes through benefit-cost approach

A comprehensive concept of economic value cannot remain dependent on only human preferences (demand curve), as it is the case of neoclassical mainstream economics, or on only production costs, as it is the case in classical political economy (supply curve) and its labour theory of value. A. Marshall, whose work is the top of neoclassical economics, concludes that economic value can arise only in the confrontation of demand and supply.

This comprehensive approach must be applied not only toward reproducible goods (that can be produced in amounts equating demand and supply), but also toward natural resources (Seják, 1997) that are not reproduced and due to this do not have classical supply curve. Nevertheless, as an asset they can be revitalized through some outlays. Under the supply curve we can understand the costs for restoration of natural resource services. Such a supply curve should be confronted with with environmental benefits (services) of ecosystems and compared with human preferences.

It is clear that in many cases it is difficult to identify both environmental benefits for humans and restoration costs. Neoclassical economics is limited by the utilitarian framework of direct use values for consumers. This utilitarian framework is characterized by using the services of nature. Methods based on revealing the WTP can reflect only a small part of specific functions of ecosystems. Growing attention is paid to expert valuations. Such valuations rank the habitats (biotopes) according to their quality for living species. Experts produce ordinal ranking of biotopes and their cardinal valuations through points. In some approaches points are transferred into monetary terms.

4.5.1. Methodology of monetary valuations of ecological functions of the territory

To save the life-supporting functions of nature means, first of all, to stop the sharp decrease of biodiversity and to retain genetic diversity in its natural development (spectrum of genes in all living organisms). Biologists estimate that there live from five to thirty million species in the world (majority of them non-identified up to now). Science identifies about 1.5 to 1.7 million species, of which 45-47 thousand are vertebrates, around one million insect species and 250-340 thousand plant species (Míchal 1992, p. 57). Biologists argue that species richness is directly proportional to the age of ecosystems in which species live.

Territories of any European state can be divided into relatively natural ecosystems and anthropogenic ecosystems. While productive anthropogenic ecosystems (agricultural land, urban and industrial land) bring economic benefits and through them they can be valued, the value of relatively natural ecosystems (mainly forest and water ecosystems) which assure the ecological stability of the territory must be derived from their ecological functions and from the costs necessary for conserving and improving the these functions.

Functions and quality of an individual environmental resource (tree, piece of agricultural land etc.) depend on its environment, on surrounding ecosystems in which it has its role.

4.5.2. Identifying ecological quality of environmental resources

Environmental resources (biotopes) can be valued according to the naturalness of their vegetation (e.g. ten grades according to Schlüter, see Míchal 1992, p. 215). Zero grade are areas without vegetation, first to fourth then athropogenic ecosystems (first grade one year monocultures without spontaneous species), seventh to ninth relatively natural ecosystems (highest quality is persistent vegetation in natural composition and structure):

Types of vegetation according to naturalness

Grades of naturalness of vegetatio (Schlüter 1982)	Verbally expressed naturalness of ecosystem (Ellenberg 1973, 1978)	Spontaneous species combination	Life time of decisive plants	Structural characteristics
0	-	-	-	Areas without vegetation
1	VI artificial	non	one year	Monocultures without spontaneous species
2-4	V nature extrinsic	secondary on part or full area	non-decisive	Artificial structures with different dynamics of spontaneous species (recede or expand)
5-6	IV nature distant	secondary fully developed	persistent	With species combination differing from grade 7
7	III nature close	Secondary semi-natural	persistent	Secondary structures meadows and forests semi-natural species
8	II natural	Predominantly natural	persistent	Natural species, changed structure
9	I natural – untouched	natural	persistent	Natural species and structures

Source: Míchal I., Ecologic stability (in Czech), Ministry of Env. CR 1992, p. 215

Grades of vegetation naturalness, from an economic viewpoint, can be understood as grades of ecological quality of an ecosystem. The open question in this approach remains whether ecosystem quality can decisively be described by the naturalness level of vegetation or whether some other characteristics are necessary (like ecosystem matureness, number of species or intensity of material-energy flows etc.). Some ecologists object that naturalness or ecosystem stability is only one necessary characteristic of quality but not sufficient (arguing that also desert can be stable). If under the grade of ecosystem stability the naturalness of vegetation is understood, then a desert cannot be assessed as stable because without vegetation it must be included under zero or first grade. Ecologically most valuable are wetlands and natural forests (grade 9), thus natural ecosystems are generally ranked 7-9. Agricultural lands as anthropogenic ecosystems are ranked by Schlüter under grades 1-4.

A more complex expert approach in valuing the territory (biotopes) has been developed in the 1980s in the Hessian federal state of Germany.

In order to identify and protect biodiversity, ecosystem functions and services (De Groot, 1992; De Groot, Wilson, Boumans, 2002), a complete list of biotope types for the Hessian state (Kompensationsverordnung GVBI. I S. 624, Anlage 3, https://umweltministerium.hessen.de) and the Czech territory was elaborated and each biotope type has been valued by an interdisciplinary team of ecologists and economists of different scientific backgrounds using points according to eight ecological characteristics, each of them with the potential point value from one to six points:

1. **biotope type matureness** (points according to phylogenetic age of species)
2. **biotope type naturalness** (6 points to completely natural, 1 point to anthropogenic)
3. **diversity of biotope type structures** (6 points to all vegetation layers)
4. **diversity of biotope type species** (points according to number of autochthonous species)
5. **rareness of biotope type** (points according to geographical and climatic uniqueness, scarcity, frequency and extent)
6. **rareness of species of biotope type** (points according to number of rare and red list species)
7. **sensitivity (vulnerability) of biotope type** (points according to rate of vulnerability through the change of habitat conditions)
8. **threat to number and quality of biotope** (points according to dependency on the change of rate of anthropogenic activities and conditions)

The sum of points achieved in the first four characteristics was multiplied by the sum of points achieved in the four remaining characteristics. The figure obtained was divided by the maximum of points (576) and multiplied by 100.

[((1 + 2 + 3 + 4) * (5 + 6 + 7 + 8)) / 576] * 100 = number of points (3-100)

The point value of respective biotope type shows its relative ecological significance compared to other biotopes**.** Based on eight of the above mentioned ecological characteristics, a complete list of biotope types for the territory of the CR was created (currently including NATURA 2000 biotopes, extended by underground water biotopes and anthropogenic biotopes) with their respective point values, showing the ranking of biotopes according to their ecological quality (biotope's life-supporting potential). The list of biotope types and their point values is enclosed (point values are related to 1 m^2 of respective biotope).

Point values were derived from eight ecological characteristics using the above written integrating scheme, with the exception of those completely anthropogenic biotopes that were deliberately given zero points. Zero point value expresses the fact that in some cases, e.g. in the case of chemically devaluated waters and wetlands, such anthropogenic biotopes even have negative impacts on the surrounding environment and should in fact have negative point values. Biotope ranking according to their point values shows relative ecological importance of an individual biotope in relation to other biotopes. Biotope ranking by their point values reflects their relative intrinsic value, i.e. their carrying capacity for ecosystem functioning.

Point values were transferred into monetary terms by the average national restoration costs necessary per one point increase. As pointed out by Turner et al. (2003, p. 494), "*from the outset, one important motivation for valuation studies has been to generate a better and more comprehensive informational base for the policy formulation and decision taking process*". The fundamental aim of environment valuation for decision-making purposes is "*to express the effect of a marginal change in ecosystem services provision in terms of a rate of trade off against other things people value*" (Randal, 2002; Hanley and Shogren, 2002).

4.5.3. Biotope restoration costs

The points for each biotope (according to the Hessian conditions, which are comparable to the CR, it is the range of 3-80 points) were converted into a monetary value by multiplying the points obtained by the **average restoration costs per one point increase** (during the 1990s in the Hessian state it was DM 0.62 per point. Point monetary value was thus the value of average costs calculated from a "basket of different types of measures" with individual cost-levels in a range between DM 0.02 and about DM 10.00 per point).

National restoration costs were estimated in the Czech Republic on the basis of a statistically significant sample of real biotope restoration projects that represented all types of revitalisation activities. Approximately 140 projects have been analysed that had already been implemented over the last five years in different parts of the Czech Republic and which have brought and would bring the increase of point value of the restored area in the long run. The financial value of one point was counted for one revitalisation project as a sum of its costs divided by a sum of the point increase expected in the long-term future. Presently, the average value of one point in the Czech Republic is set at €0.4.

4.5.4. Linking biotope values with CLC (Corine land-cover) (satellite images)

By combining biotope values with the CLC (Corine Land Cover) project results, the development of total national value of biotopes as the monetary value of national natural capital was quantified. Changes in natural capital of the Czech Republic were monitored by comparing the areas of CLC items 2000 (€587 billion) with the areas of CLC items 1990 (CZK 568 billion). It means that during the 1990s (the period of transitioning from the centrally planned to market economic system) some ecologically positive changes took place; these changes were caused mainly by transferring some arable lands to meadows and pastures and by expanding the forest area (total increase by approximately €1.9 billion annually).

Tab. 4.1

Table of basic data for calculating the value of natural capital in the CR 1990				
CORINE LAND COVER 1:100000	**Surfaces**	**Points**	**Surfaces*pionts**	**Nat. capital in CZK**
1.1.1. Continuous urban fabric	14636361	2.70	39518174	488444627
1.1.2. Discontinuous urban fabric	4114338107	6.84	28142072651	347836017960
1.2.1. Industrial or commercial units	521680748	1.20	626016897	7737568847
1.2.2. Road and rail networks and assoc. land	48078544	3.20	153851340	1901602559
1.2.3. Port areas	1502605	1.80	2704689	33429959

1.2.4. Airports	56090253	14.82	831257547	10274343286
1.3.1. Mineral extraction sites	180941815	3.25	588060900	7268432719
1.3.2. Dump sites	154370414	4.75	733259465	9063086990
1.3.3. Construction sites	21599229	0.60	12959538	160179885
1.4.1. Green urban areas	65245357	17.10	1115695600	13789997621
1.4.2. Sport and leisure facilities	118778026	16.80	1995470835	24664019520
2.1.1. Non-irrigated arable land	34596715279	10.35	358076003142	4425819398836
2.2.1. Vineyards	111180537	13.20	1467583091	18139327002
2.2.2. Fruit trees and berry plantations	327530178	12.20	3995868174	49388930634
2.3.1. Pastures	2525860021	30.00	75775800622	936588895689
2.4.2. Complex cultivation patterns	412006077	13.05	5376679299	66455756132
2.4.3. Agricult. lands with natural vegetation	7166208956	20.05	143682489577	1775915571176
3.1.1. Broad-leaved forest	2499374237	41.13	102799262355	1270598882710
3.1.2. Coniferous forest	16571358907	21.97	364072755187	4499939254113
3.1.3. Mixed forest	5854737543	29.63	173475873396	2144161795170
3.2.1. Natural grassland	420082423	30.00	12602472703	155766562606
3.2.2. Moors and heathlands	26198255	58.42	1530502035	18917005150
3.2.4. Transitional woodland-shrub	2476234690	31.70	78496639665	970218466261
3.3.2. Bare rocks	2143299	47.85	102556869	1267602898
3.3.4. Burnt areas	1171728	21.00	24606292	304133766
4.1.1. Inland marches	53573302	28.82	1543982560	19083624447
4.1.2. Peat bogs	37587184	58.92	2214636852	27372911494
5.1.1. Stream courses	42827887	19.05	815871253	10084168687
5.1.2. Water bodies	493079472	39.54	19496362320	240975038273
Czech Republic total	78915131433		1379790813027	**17 054 214 449 018**

Table of basic data for calculating the value of natural capital in the CR 2000

CORINE LAND COVER 1:100000	Surfaces in m2	Points/m2	Surfaces*pionts	Nat. capital in CZK
1.1.1. Continuous urban fabric	14636361	2.70	39518174	488444627
1.1.2. Discontinuous urban fabric	4161694885	6.84	28465993013	351839673638
1.2.1. Industrial or commercial units	547457966	1.20	656949560	8119896559
1.2.2. Road and rail networks and assoc. land	52722302	3.20	168711365	2085272476
1.2.3. Port areas	1502605	1.80	2704689	33429959
1.2.4. Airports	56265855	14.82	833859968	10306509210
1.3.1. Mineral extraction sites	170931219	3.25	555526461	6866307060
1.3.2. Dump sites	138242534	4.75	656652034	8116219143
1.3.3. Construction sites	8562734	0.60	5137640	63501232
1.4.1. Green urban areas	65617246	17.10	1122054901	13868598574
1.4.2. Sport and leisure facilities	128068620	16.80	2151552808	26593192709
2.1.1. Non-irrigated arable land	32087263082	1035	332103172900	4104795217044
2.2.1. Vineyards	119815296	13.20	1581561912	19548105229
2.2.2. Fruit trees and berry plantations	325389925	12.20	3969757086	49066197588
2.3.1. Pastures	5327327189	30.00	159819815656	1975372921510

2.4.2. Complex cultivation patterns	426197708	13.05	5561880089	68744837902
2.4.3. Agricult. lands with natural vegetation	6750468326	20.05	135346889937	1672887559625
3.1.1. Broad-leaved forest	2530991140	41.13	104099665608	1286671866914
3.1.2. Coniferous forest	17012275950	21.97	373759702617	4619669924344
3.1.3. Mixed forest	6043384868	29.63	179065493629	2213249501253
3.2.1. Natural grassland	416475694	30.00	12494270814	154429187265
3.2.2. Moors and heathlands	27063512	58.42	1581050344	19541782256
3.2.4. Transitional woodland-shrub	1856866805	31.70	58862677728	727542696714
3.3.2. Bare rocks	2143299	47.85	102556869	1267602898
3.3.4. Burnt areas	0	21.00	0	0
4.1.1. Inland marches	53775323	28.82	1549804817	19155587538
4.1.2. Peat bogs	37108297	58.92	2186420871	27024161963
5.1.1. Stream courses	43028879	19.05	819700141	10131493748
5.1.2. Water bodies	509853815	39.54	20159619851	249172901354
Czech Republic total	78915131433		1427722701483	**17 646 652 590 330**

At the same time, the period of the 1990s witnessed a growing consumption of natural capital in the Czech Republic. Against the above mentioned positive tendency (reflected by CLC images) there was on the other hand also a negative tendency of developing industrial zones and commercial and residential areas on agricultural lands (not reflected by the CLC, being mostly less than 25 ha). An order of natural capital consumption allowances can be estimated from the agricultural land use statistics. Such statistics is generated by the Law on Agricultural Land Protection no.334/1992 Coll.

The appropriations of agricultural land for non-agricultural use (creation of industrial zones, housing, construction of transport lines etc.) showed that at the beginning of the 2000s, from around 10 to 20 thousand hectares were appropriated annually on average. The annual depreciation of natural capital in the Czech Republic can thus be estimated (based on the consumption of agricultural land only) at approximately CZK 10 bln. Agricultural land removals and payments in 2012 are showed in the next table.

Agricultural land removal and payments in 2012 in the CR

		Unit	Removal of land								
			Total	including							
				Apartm. constr.	Industr. Constr.	Mining minerals	Transp. Netw.	Water Manag.	Recr. sport	Afforest.	other
Number of payers			5820								
Agric. land removal with consent	permanent	ha	4836	581	340	2225	228	350	146	621	345
	temporary	ha	1361	4	271	693	184	5	40	21	143
Agric. land with prescr. payments	§ 11/9	ha	3129	1	6	3012	1	0	1	94	14
	§ 11/10	ha	812	13	338	15	211	9	65	8	152
	§ 11/1b	ha	6065	5	1810	3564	266	2	159	4	254
Charges for removal	§ 11/9	CZK thous.	17143	9	32	15441	829	20	395	204	213
	§ 11/10	CZK thous.	315230	3640	171028	305	62135	1189	19016	0	57917
	§ 11/1b	CZK thous.	14164	41	6203	3569	1001	233	1309	1	1807

Having the same economic dimension, such natural capital consumption allowances can be deducted from the conventional annual income flow (GDP, GNP, NDP, NNP).

Measuring the rate of decoupling can be done by comparing the ratio among the development of GDP in constant prices and the development of natural capital value. As the total GDP development in constant prices showed stagnation in the transitioning Czech economy in the period 1990-2000 (from CZK 1,449.2 bln. in 1990 to 1,467.3 in 2000, i.e. by index of 101.2 %) and as the total natural capital value slightly increased (from CZK 17,054 bln. in 1990 to 17,647 in 2000), there was slight decoupling between the GDP and the natural capital. This was achieved especially due to positive structural changes in biotopes.

Beside these goals we developed the table and maps of economic and ecological functions of the territory of the Czech Republic (these are LC items valued by means of administrative prices of land and other natural resources for economic functions and through integrating the Hessian biotopes and using their monetary values for ecological functions). Information on these values is given in table 4.2.

Values of ecological and economic functions of the Czech territories **Table 4.2**

LAND COVER 1:100000	Points		Points	CZK/m^2	CZK/m^2	CZK/m^2	CZK/m^2	
	min	max	mean	min.	max.	ecol. f.	econ. f.	
1.1.1. Continuous urban fabric	3	3	**3**	37	37	**37**	35-2250	acc. to urban size
1.1.2. Discontinuous urban fabric	3	7	**5**	37	87	**62**	35-2250	acc. to urban size
1.2.1. Industrial or commercial units	3	3	**3**	37	37	**37**	35-2250	acc. to urban size
1.2.2. Road and rail networks and assoc. land	3	7	**5**	37	87	**62**	35-2250	acc. to urban size
1.2.3. Port areas	23	23	**23**	285	285	**285**	35-2250	acc. to urban size
1.2.4. Airports	3	23	**13**	37	285	**161**	35-2250	acc. to urban size
1.3.1. Mineral extraction sites	6	18	**12**	74	223	**149**	35-2250	acc. to urban size
1.3.2. Dump sites	6	6	**6**	74	74	**74**	1	
1.3.3. Construction sites	6	6	**6**	74	74	**74**	35-2250	acc. to urban size
1.4.1. Green urban areas	14	20	**17**	174	248	**211**	35-2250	acc. to urban size
1.4.2. Sport and leisure facilities	10	20	**15**	124	248	**186**	13.9-9.5	
2.1.1. Non-irrigated arable land	11	13	**12**	136	161	**149**	1.85-9.05	acc. to soil quality
2.1.2. Irrigated arable land	13	13	**13**	161	161	**161**	1.85-9.05	acc. to soil quality
2.2.1. Vineyards	17	17	**17**	211	211	**211**	42	
2.2.2. Fruit trees and berry plantations	14	23	**18,5**	174	285	**229**	42	
2.3.1. Pastures	21	59	**40**	260	732	**496**	1-4.50	acc. to soil quality
2.4.1. Annual, permanent crops	13	23	**18**	161	285	**223**	1-4.50	acc. to soil quality
2.4.2. Complex cultivation patterns	20	44	**32**	248	546	**397**	21.90-9.05	acc. to soil quality
2.4.3. Agricult. lands with natural vegetation	31	50	**40,5**	384	620	**502**	1-4.50	acc. to soil quality
2.4.4. Agro-forestry areas	31	60	**45,5**	384	744	**564**	18	
3.1.1. Broad-leaved forest	58	72	**65**	719	893	**806**	30	
3.1.2. Coniferous forest	26	62	**44**	322	769	**546**	22	
3.1.3. Mixed forest	44	67	**55,5**	546	831	**688**	26	
3.2.1. Natural grassland	27	59	**43**	335	732	**533**	2.60	
3.2.2. Moors and heathlands	36	41	**38,5**	446	508	**477**	1	
3.2.4. Transitional woodland-shrub	26	59	**42,5**	322	732	**527**	1	
3.3.1. Beaches, dunes, sands	14	39	**26,5**	174	484	**329**	1	
3.3.2. Bare rocks	23	50	**36,5**	285	620	**453**	1	
3.3.3 Sparsely vegetated areas	21	50	**35,5**	260	620	**440**	1	
3.3.4. Burnt areas	21	21	**21**	260	260	**260**	1	
4.1.1. Inland marches	44	56	**50**	546	694	**620**	1	
4.1.2. Peat bogs	80	80	**80**	992	992	**992**	1	
5.1.1. Stream courses	47	73	**60**	583	905	**744**	10	
5.1.2. Water bodies	35	79	**57**	434	980	**707**	10	

With this methodological approach a value map of biotopes of the Czech Republic was constructed and case studies were performed (see Enclosure 1). Results were presented to the Czech minister of environment and to other politicians.

The results obtained on the basis of the selected approach are important and stimulating in several ways:

1. They are important for national accounting. By combining the evaluation of ecological functions of the environment and the land cover approach, values can be obtained expressing and quantifying the value of national natural capital. Using digital mapping and computers it is relatively easy to calculate the total value of the environmental (ecological or life-support) functions of the Czech territory. Changes in natural capital of the Czech Republic were monitored by comparing the areas of CLC items 2000 (€587 billion) with the areas of CLC items 1990 (CZK 568 billion). It means that during the 1990s (period of transitioning from the centrally planned to market economic system) some ecologically positive changes took place; these changes were caused mainly by transferring some arable lands to meadows and pastures and by increasing the area of forests (total increase yearly by about €1.9 billion).

2. The results can be important for territorial (land use) planning and decision-making. By comparing the values of environmental functions and economic functions for a particular territory we can generate relevant information for political decisions.

3. The results can be used on the micro-economic level for constructing and implementing economic instruments (fees) for activities affecting nature and the environment. New economic instruments can help to bring about more sustainable behaviour by economic actors.

4.5.5. Utilizing environmental values as economic instruments

Nature and landscape protection authorities in many European countries still do not use economic instruments expressing environmental values. Creating such list of biotopes and their values is the first assumption for changing the attitudes of economic agents toward nature and landscape.
The incorporation of environmental values into economic systems will increase the importance of environmental authorities and of nature and landscape conservation authorities, which will become comparable with other economic ministries. They will not be dependent on public funds that thus can be reduced.

Incorporating environmental values into economic systems will enable to control effectively the equilibrium between economic and environmental aspects in the use of territory.

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Utilitarian welfare economists tend to argue that the values generated by the Hessian method and by other ecosystem methods (in the Czech Republic, for example, these include the ecosystem method of valuing integrative functions of forests, developed at Mendel University in Brno) do not reflect the demand side aspect, i.e., they do not reflect the current demand of consumers for nature and biodiversity. From the narrowly utilitarian point of view they may be right, because the utilitarian value concept reflects the current wants of consumers by means of summing the individual consumer's willingness to pay. But it is exactly this utilitarian approach that has contributed to the destruction of the world's most valuable ecosystems over the past one hundred years.

The protection of environment and biodiversity is the domain of government and parliamentary (including the EU bodies) political decision-making processes, as confirmed e.g. by the recent Millennium Ecosystems Assessment draft. Therefore, the **Hessian biotope values reflect the real human demand**, i.e. the need for protecting the rest of the valuable natural areas that are quickly disappearing due to the self-interested behaviour of economic agents mainly from the developed economies and due to the daily fight for survival of billions of people in the indebted developing countries.

Hessian values reflect both social costs and social benefits (demand). The costs are expressed by the real average costs of revitalisation projects implemented which the society has been recently paying to protect and to renew the ecosystem services. The social benefits are expressed by the need to protect the life-supporting services of ecosystems. Nevertheless, such social benefits can hardly be expressed by the subjective utilitarian methods of revealing the individual consumer's willingness to pay for the non-market parts of the environment and biodiversity. More efficiently, they can be generated by interdisciplinary scientific teams of natural and social scientists and respectively approved by executive and parliamentary bodies within the political decision-making processes of national states and international communities with real interest in biodiversity protection.

On the other hand, the CV methods, being based on self-interested individualistic and utilitarian concept of economic value, are improper to use in revealing environmental, non-use values. From this viewpoint it is then understandable that after about twenty years of developing CV methodology one of the establishers refused to use it for measuring non-use damages on environment (Desvousges, 1995).

The main ethical challenge for neoclassical economics consists in the fact that while neoclassical framework reflects only subjestivistic and individualistic utilitarian concept of value, ecological economists incorporate into the economic value also the intrinsic value of nature, they even take it as the primary value decisive for sustaining the life on Earth, while the traditional utilitarian value is ranked as a secondary value. Such an intrinsic value can be revealed effectively by means of interdisciplinary research teams and incorporated into economic system by means of political decisions.

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At the end of this part, let us remember why economic monetary valuations of natural and environmental resources are important.

First, environmental resources often have no market price and are used as a free of charge goods. For example clean air cannot be sold directly as market commodity. On the other hand, if emission limits are introduced, then environment stops to be used as free goods and becomes to be treated as private goods. Pollution becomes a market commodity. Nevertheless, even in this situation the majority of environmental resources remain out of control and their valuation is the necessary assumption for changing the trends in overuse of environment.

Second, environmental valuations support the consistency in decision making processes, as they create an instrument for achieving the equilibrium among economic and environmental aspects in the use of territory. Such valuations prevent ineffective allocation of resources.

Third, environmental valuations and values can serve as a political instrument in showing that environment is important and scarce.

Fourth, in environmental valuations researchers and politicians need not rely on individualistic and subjectivistic valuation methods and must utilize the interdisciplinary knowledge of research teams. Only monetary valuations of environment are able to incorporate nature and landscape and all ecological problems into economic system and into economic decision-making processes.

4.5.6 Values of biotope types in the CR

The list of biotope values is a result of a three year project (2001-2003) carried out by the interdisciplinary research team of about 30 researchers with different scientific backgrounds.

Abbreviations and explanations

M = matureness

N = naturalness

DL = Diversity of layers-structures

DS = Diversity of species

RB = Rareness of biotope

RS = Rareness of species of this biotope

SB = Sensibility (vulnerability) of biotope

TB = Threat of number and quality of biotope

Su % = Sum of points in % from maximal possible sum (48)

ZBH= (Z+P+DS+DD)*(VB+VD+CB+OB) (max. 576)

PV = [(Z+P+DS+DD)*(VB+VD+CB+OB)]*100/576
(in % from max. possible value [576])

Point valuation of certain parameter is min. 1 and maximally 6 points

Natural and quasi-natural biotope types

Semi-natural biotope types

Anthropogenic (abiotic) biotope types

VALUES OF BIOTOPE TYPES IN THE CZECH REPUBLIC

	Biotope type	Parameter								Su.	ZBH	PV
		M	N	DL	DS	RB	RS	SB	TB	%		
1	**V00.1 Interstitial underground waters**	6	6	2	1	2	1	6	3	56	180	**31**
2	**V00.2 Crack underground waters**	6	6	2	1	4	1	6	4	63	225	**39**
3	**V0.1 Underground carst lakes**	6	6	3	2	6	1	4	3	65	221	**36**
4	**V0.2 Underground carst streams**	6	6	3	3	6	1	4	3	67	252	**44**
5	**V1 Macrophyte vegetation of naturaly eutrophic and mesotrofic still waters**	5	5	4	4	4	4	4	3	69	270	**47**
6	**V2.1 Macrophyte vegetation of shallow still waters**	5	6	4	4	4	3	5	4	73	304	**53**
7	**V2.2 Periodic still waters**	5	6	3	3	4	2	5	4	67	255	**44**
8	**V2.3 Waters of specific chemism**	5	6	3	2	6	1	4	3	63	224	**39**
9	**V3 Macrophyte vegetation of oligotrophic lakes and pools**	6	6	4	3	6	3	5	4	77	342	**59**
10	**V4 Macrophyte vegetation of water streams V4.1 Spring ditchies**	6	6	3	3	4	1	5	3	65	234	**41**
11	**V4 Macrophyte vegetation of water streams V4.2 Trout belts of water streams**	6	6	3	4	4	2	5	3	69	266	**46**
12	**V4 Macrophyte vegetation of water streams V4.3 *Thymallidae* belts of water streams**	6	6	4	4	4	2	5	4	73	300	**52**
13	**V4 Macrophyte vegetation of water streams V4.4 Barbel belts of water streams**	5	6	4	5	4	3	4	4	73	300	**52**
14	**V4 Macrophyte vegetation of water streams V4.5 Bream belts of water streams**	5	6	5	5	4	6	4	3	79	357	**62**
15	**V5 *Charophycae* vegetation**	6	6	3	3	6	3	5	4	75	324	**56**
16	**V6 *Isoëtes* vegetation**	6	6	3	2	6	2	6	3	71	289	**50**
17	**M1.1 Reed beds of eutrophic still waters**	4	5	3	4	2	2	3	3	54	160	**28**
18	**M1.2 Halophilous reed and sedge beds**	5	5	3	4	6	3	4	5	73	306	**53**
19	**M1.3 Eutrophic vegetation of muddy substrates**	4	5	3	4	4	3	3	3	60	208	**36**
20	**M1.4 Riverine reed beds**	4	6	3	3	2	2	3	3	54	160	**28**
21	**M1.5 Reed vegetation of brooks**	4	6	3	3	4	2	3	3	58	192	**33**
22	**M1.6 Mesotrophic vegetation of muddy substrates**	5	5	3	3	4	3	3	3	60	208	**36**
23	**M1.7 Tall-sedge beds**	4	5	3	3	2	2	3	3	52	150	**26**
24	**M1.8 Calcareous fens with *Cladium mariscus***	5	6	3	4	6	3	5	5	77	342	**59**
25	**M2.1 Vegetation of exposed fishpond bottoms**	5	5	3	3	6	2	4	3	65	240	**42**

26	**M2.2 Annual vegetation on wet sand**	**5**	**5**	**2**	**3**	**6**	**2**	**5**	**3**	65	240	**42**
27	**M2.3 Vegetation of exposed bottoms in warm areas**	**5**	**5**	**3**	**3**	**6**	**3**	**5**	**3**	69	272	**47**
28	**M2.4 Vegetation of annual halophilous grasses**	**6**	**5**	**2**	**2**	**6**	**2**	**5**	**6**	71	285	**49**
29	**M3 Vegetation of perennial amphibious herbs**	**5**	**6**	**3**	**3**	**4**	**2**	**4**	**3**	63	221	**38**
30	**M4.1 Unvegetated river gravel banks**	**6**	**6**	**2**	**2**	**4**	**1**	**2**	**4**	56	176	**31**
31	**M4.2 River gravel banks with *Myricaria germanica***	**6**	**6**	**3**	**2**	**6**	**2**	**4**	**4**	69	272	**47**
32	**M4.3 River gravel banks with *Calamagrostis pseudophragmites***	**5**	**6**	**3**	**2**	**6**	**2**	**3**	**4**	65	240	**42**
33	**M5 *Petasites* fringes of montane brooks**	**5**	**5**	**4**	**4**	**4**	**2**	**3**	**4**	65	234	**41**
34	**M6 Muddy river banks**	**3**	**6**	**3**	**4**	**4**	**2**	**3**	**3**	58	192	**33**
35	**M7 Herbaceous fringes of lowland rivers**	**4**	**5**	**3**	**4**	**4**	**2**	**3**	**3**	58	192	**33**
36	**R0.1 Simple waters springs**	**6**	**6**	**2**	**2**	**4**	**1**	**5**	**3**	60	208	**36**
37	**R0.2 Thermal and mineral springs**	**6**	**6**	**2**	**2**	**4**	**1**	**4**	**3**	58	192	**33**
38	**R1.1 Meadow springs with tufa formation**	**5**	**5**	**3**	**4**	**6**	**4**	**5**	**6**	79	357	**62**
39	**R1.2 Meadow springs without tufa formation**	**5**	**5**	**3**	**4**	**6**	**3**	**5**	**5**	75	323	**56**
40	**R1.3 Forest springs with tufa formation**	**5**	**6**	**4**	**2**	**6**	**3**	**4**	**4**	71	289	**50**
41	**R1.4 Forest springs without tufa formation**	**5**	**6**	**4**	**3**	**6**	**3**	**4**	**4**	73	306	**53**
42	**R1.5 Subalpine springs**	**5**	**6**	**3**	**4**	**6**	**3**	**5**	**4**	75	324	**56**
43	**R2.1 Calcareous fens**	**5**	**5**	**3**	**4**	**4**	**5**	**5**	**5**	75	324	**56**
44	**R2.2 Acidic moss-rich fens**	**5**	**5**	**3**	**4**	**6**	**3**	**5**	**4**	73	306	**53**
45	**R2.3 Transition mires**	**5**	**6**	**4**	**4**	**4**	**4**	**5**	**4**	75	323	**56**
46	**R2.4 Peatsoils with *Rhynchospora alba***	**6**	**6**	**3**	**4**	**6**	**3**	**6**	**5**	81	380	**66**
47	**R3.1 Active raised bogs**	**6**	**6**	**4**	**3**	**6**	**3**	**6**	**5**	81	380	**66**
48	**R3.2 Raised bogs with *Pinus mugo***	**6**	**6**	**4**	**3**	**6**	**3**	**6**	**5**	81	380	**66**
49	**R3.3 Bog hollows**	**6**	**6**	**3**	**3**	**6**	**3**	**6**	**5**	79	360	**63**
50	**S1.1 Chasmophytic vegetation of calcareous cliffs and boulder screes**	**5**	**6**	**3**	**5**	**6**	**5**	**2**	**4**	75	323	**56**
51	**S1.2 Chasmophytic vegetation of siliceous cliffs and boulder screes**	**5**	**6**	**3**	**5**	**4**	**4**	**2**	**4**	69	266	**46**
52	**S1.3 Tall grasslands on rock ledges**	**5**	**6**	**3**	**4**	**6**	**3**	**2**	**4**	69	270	**47**
53	**S1.4 Tall-forb vegetation of fine-soil-rich boulder screes**	**5**	**6**	**3**	**3**	**6**	**3**	**2**	**4**	67	255	**44**
54	**S1.5 Ribes alpinum scrub on cliffs and boulder screes**	**5**	**6**	**4**	**4**	**6**	**2**	**2**	**4**	69	266	**46**
55	**S2 Mobile screes**	**6**	**6**	**3**	**4**	**6**	**2**	**2**	**3**	67	247	**43**
56	**S3 Caves**	**6**	**6**	**4**	**3**	**6**	**1**	**2**	**3**	65	228	**40**
57	**A1.1 Wind-swept alpine grasslands**	**6**	**6**	**3**	**3**	**6**	**4**	**5**	**4**	77	342	**59**
58	**A1.2 Closed alpine grasslands**	**6**	**5**	**3**	**3**	**6**	**4**	**5**	**4**	75	323	**56**
59	**A2.1 Alpine heathlands**	**6**	**6**	**4**	**3**	**6**	**3**	**4**	**4**	75	323	**56**
60	**A2.2 Subalpine *Vaccinium* vegetation**	**6**	**6**	**4**	**3**	**6**	**3**	**4**	**4**	75	323	**56**
61	**A3 Snow beds**	**6**	**6**	**3**	**3**	**6**	**3**	**5**	**4**	75	324	**56**
62	**A4.1 Subalpine tall-herbs vegetation**	**6**	**6**	**3**	**4**	**6**	**4**	**4**	**4**	77	342	**59**
63	**A4.2 Subalpine tall-forb vegetation**	**6**	**6**	**4**	**5**	**6**	**4**	**4**	**4**	81	378	**66**
64	**A4.3 Subalpine tall-fern vegetation**	**6**	**6**	**4**	**4**	**6**	**4**	**4**	**4**	79	360	**63**
65	**A5 Cliff vegetation in the Sudeten cirques**	**6**	**6**	**3**	**5**	**6**	**4**	**5**	**4**	81	380	**66**
66	**A6 Acidophilous vegetation of alpine cliffs and boulder screes**	**6**	**6**	**3**	**5**	**6**	**4**	**5**	**4**	81	380	**66**
67	**A7 *Pinus mugo* scrub**	**6**	**6**	**4**	**5**	**6**	**3**	**4**	**3**	77	336	**58**
68	**A8.1 *Salix lapponum* subalpine scrub**	**6**	**6**	**4**	**4**	**6**	**3**	**4**	**4**	77	340	**59**
69	**A8.2 Subalpine deciduous tall scrub**	**5**	**6**	**4**	**5**	**6**	**2**	**4**	**4**	75	320	**56**
70	**T1.1 Mesic *Arrhenatherum* meadows**	**3**	**4**	**4**	**5**	**2**	**3**	**4**	**3**	58	192	**33**
71	**T1.2 Montane *Trisetum* meadows**	**4**	**5**	**4**	**4**	**4**	**4**	**4**	**5**	71	289	**50**
72	**T1.3 *Cynosurus* pastures**	**3**	**4**	**4**	**4**	**4**	**2**	**4**	**5**	63	225	**39**
73	**T1.4 Alluvial *Alopecurus* meadows**	**4**	**5**	**4**	**6**	**2**	**3**	**5**	**4**	69	266	**46**
74	**T1.5 Wet *Cirsium* meadows**	**4**	**5**	**4**	**6**	**2**	**4**	**5**	**4**	71	285	**49**
75	**T1.6 Wet *Filipendula* grasslands**	**4**	**5**	**4**	**6**	**2**	**4**	**4**	**4**	69	266	**46**
76	**T1.7 Continantal inundated meadows**	**4**	**6**	**4**	**6**	**6**	**4**	**5**	**4**	81	380	**66**
77	**T1.8 Continental tall-forb vegetation**	**4**	**5**	**4**	**6**	**6**	**4**	**5**	**4**	79	361	**63**
78	**T1.9 Intermittently wet *Molinia* meadows**	**5**	**5**	**4**	**5**	**4**	**5**	**5**	**5**	79	361	**63**
79	**T1.10 Vegetation of wet disturbed soils**	**3**	**4**	**4**	**4**	**4**	**3**	**4**	**4**	63	225	**39**
80	**T2.1 Subalpine *Nardus* grasslands**	**5**	**5**	**3**	**4**	**6**	**4**	**5**	**4**	75	323	**56**
81	**T2.2 Montane *Nardus* grasslands with alpine species**	**4**	**5**	**3**	**4**	**6**	**4**	**5**	**4**	73	304	**53**
82	**T2.3 Submontane and montane *Nardus* grasslands**	**3**	**5**	**3**	**4**	**4**	**3**	**4**	**4**	63	225	**39**
83	**T3.1 Rock-outcrop vegetation with *Festuca pallens***	**5**	**6**	**4**	**6**	**4**	**6**	**4**	**4**	81	378	**66**
84	**T3.2 *Sesleria* grasslands**	**5**	**6**	**4**	**5**	**6**	**5**	**5**	**4**	83	400	**69**
85	**T3.3 Narrow-leaved dry grasslands**	**5**	**6**	**4**	**6**	**6**	**6**	**5**	**6**	92	483	**84**
86	**T3.4 Broad-leaved dry grasslands**	**4**	**5**	**4**	**6**	**4**	**6**	**5**	**4**	79	361	**63**
87	**T3.5 Acidofilous dry grasslands**	**4**	**5**	**4**	**6**	**4**	**5**	**4**	**4**	75	323	**56**
88	**T4.1 Dry herbaceous fringes**	**4**	**5**	**4**	**6**	**4**	**5**	**5**	**4**	77	342	**59**
89	**T4.2 Mesic herbaceous fringes**	**3**	**5**	**4**	**5**	**2**	**4**	**4**	**4**	65	238	**41**
90	**T5.1 Annual vegetation of sand dunes**	**4**	**5**	**2**	**4**	**6**	**3**	**4**	**4**	67	255	**44**
91	**T5.2 Open sand grasslands with *Corynephorus canescens***	**4**	**5**	**2**	**3**	**6**	**3**	**4**	**4**	65	238	**41**
92	**T5.3 *Festuca* sand grasslands**	**4**	**5**	**3**	**5**	**6**	**3**	**4**	**4**	71	289	**50**

93	**T5.4 Pannonian sand steppe grasslands**	**5**	**5**	**3**	**5**	**6**	**5**	**5**	**4**	79	360	**63**
94	**T5.5 Submontane acidophilous grasslands**	**4**	**4**	**3**	**4**	**4**	**2**	**3**	**3**	56	180	**31**
95	**T6.1 Acidophilous vegetation of spring therophytes and succulents**	**5**	**6**	**3**	**5**	**4**	**3**	**4**	**4**	71	285	**49**
96	**T6.2 Basiphilous vegetation of spring therophytes and succulents**	**5**	**6**	**3**	**5**	**6**	**4**	**4**	**4**	77	342	**59**
97	**T7 Inland salt marshes**	**6**	**5**	**3**	**5**	**6**	**4**	**6**	**6**	85	418	**73**
98	**T8.1 Dry lowland and colline heaths**	**4**	**5**	**4**	**5**	**6**	**4**	**3**	**5**	75	324	**56**
99	**T8.2 Secondary submontane and montane heaths**	**4**	**4**	**4**	**5**	**4**	**2**	**4**	**4**	65	238	**41**
100	**T8.3 *Vaccinium* vegetation of cliffs and boulder screes**	**6**	**6**	**4**	**4**	**6**	**2**	**3**	**3**	71	280	**49**
101	**K1 Willow carrs**	**4**	**5**	**5**	**5**	**2**	**2**	**4**	**3**	63	209	**36**
102	**K2.1 Willow scrub of loamy and sandy river banks**	**4**	**5**	**5**	**5**	**2**	**2**	**4**	**3**	63	209	**36**
103	**K2.2 Willow scrub of river banks**	**4**	**6**	**5**	**5**	**6**	**2**	**4**	**3**	73	300	**52**
104	**K3 Tall mesic and xeric scrub**	**4**	**5**	**5**	**5**	**2**	**3**	**2**	**3**	60	190	**33**
105	**K4 Low xeric scrub**	**4**	**5**	**5**	**5**	**6**	**4**	**3**	**4**	75	323	**56**
106	**L1 Alder carrs**	**5**	**6**	**5**	**5**	**4**	**3**	**4**	**4**	75	315	**55**
107	**L2.1 Montane grey alder galleries**	**5**	**6**	**5**	**6**	**6**	**3**	**3**	**3**	77	330	**57**
108	**L2.2 Ash-alder alluvial forests**	**4**	**6**	**6**	**6**	**2**	**3**	**3**	**3**	69	242	**42**
109	**L2.3 Hardwood forests of lowland rivers**	**4**	**6**	**6**	**5**	**6**	**4**	**3**	**5**	81	378	**66**
110	**L2.4 Willow-poplar forests of lowland rivers**	**4**	**6**	**6**	**6**	**6**	**3**	**3**	**5**	81	374	**65**
111	**L3.1 Hercynian oak-hornbeam forests**	**4**	**6**	**6**	**5**	**3**	**3**	**3**	**4**	71	273	**47**
112	**L3.2 Polonian oak-hornbeam forests**	**4**	**6**	**6**	**5**	**5**	**3**	**3**	**4**	75	315	**55**
113	**L3.3Carpathian oak-hornbeam forests**	**4**	**6**	**6**	**5**	**5**	**4**	**3**	**4**	77	336	**58**
114	**L3.4 Pannonian oak-hornbeam forests**	**4**	**6**	**6**	**6**	**5**	**4**	**3**	**4**	79	352	**61**
115	**L4 Ravine forests**	**4**	**6**	**6**	**6**	**2**	**3**	**3**	**3**	69	242	**42**
116	**L5.1 Herb-rich beech forests**	**4**	**6**	**6**	**4**	**3**	**3**	**3**	**4**	69	260	**45**
117	**L5.2 Montane sycamore-beech forests**	**4**	**6**	**6**	**4**	**5**	**3**	**3**	**4**	73	300	**52**
118	**L5.3 Limestone beech forests**	**4**	**6**	**6**	**5**	**5**	**4**	**3**	**5**	79	357	**62**
119	**L5.4 Acidophilous beech forests**	**4**	**6**	**5**	**3**	**3**	**2**	**3**	**4**	63	216	**38**
120	**L6.1 Peri-Alpidic basiphilous thermophilous oak forests**	**5**	**6**	**6**	**5**	**6**	**4**	**3**	**5**	83	396	**69**
121	**L6.2 Pannonian thermophilous oak forests on loess**	**5**	**6**	**6**	**6**	**6**	**4**	**3**	**5**	85	414	**72**
122	**L6.3 Pannonian thermophilous oak forests on sand**	**5**	**6**	**6**	**5**	**6**	**4**	**3**	**5**	83	396	**69**
123	**L6.4 Central European basiphilous thermophilous oak forests**	**5**	**6**	**6**	**6**	**4**	**4**	**3**	**4**	79	345	**60**
124	**L6.5 Acidophilous thermophilous oak forests**	**4**	**6**	**6**	**5**	**4**	**3**	**3**	**4**	73	294	**51**
125	**L7.1 Dry acidophilous oak forests**	**4**	**6**	**5**	**3**	**3**	**2**	**3**	**4**	63	216	**38**
126	**L7.2 Wet acidophilous oak forests**	**4**	**6**	**5**	**3**	**4**	**2**	**3**	**4**	65	234	**41**
127	**L7.3 Subcontinental pine-oak forests**	**5**	**6**	**5**	**3**	**4**	**2**	**3**	**4**	67	247	**43**
128	**L7.4 Acidophilous oak forests on sand**	**5**	**6**	**5**	**3**	**6**	**3**	**3**	**4**	73	304	**53**
129	**L8.1 Boreo-continental pine forests**	**5**	**6**	**5**	**3**	**4**	**2**	**3**	**3**	65	228	**40**
130	**L8.2 Forest-steppe pine forests**	**5**	**6**	**6**	**5**	**6**	**3**	**3**	**4**	79	352	**61**
131	**L8.3 Peri-Alpidic serpentine pine forests**	**5**	**6**	**5**	**5**	**6**	**3**	**3**	**4**	77	336	**58**
132	**L9.1 Montane *Calamagrostis* spruce forests**	**5**	**6**	**5**	**3**	**3**	**2**	**3**	**3**	63	209	**36**
133	**L9.2 Bog spruce forests**	**5**	**6**	**5**	**3**	**3**	**3**	**3**	**4**	67	247	**43**
134	**L9.3 Montane *Athirium* spruce forests**	**5**	**6**	**5**	**3**	**4**	**3**	**3**	**3**	67	247	**43**
135	**L10.1 Birch mire forests**	**5**	**6**	**5**	**3**	**6**	**3**	**4**	**4**	75	323	**56**
136	**L10.2 Pine mire forests with *Vaccinium***	**6**	**6**	**5**	**3**	**6**	**2**	**4**	**4**	75	320	**56**
137	**L10.3 Pine forests of continental mires with *Eriophorum***	**6**	**6**	**5**	**3**	**6**	**3**	**4**	**4**	77	340	**59**
138	**L10.4 *Pinus rotundata* bog forests**	**6**	**6**	**5**	**3**	**6**	**3**	**4**	**4**	77	340	**59**
139	**XV1 Vegetation of new water surfaces**	**2**	**3**	**3**	**2**	**2**	**2**	**2**	**3**	40	90	**16**
140	**XV2 Degraded water biota**	**1**	**3**	**3**	**3**	**2**	**1**	**3**	**2**	38	80	**14**
141	**XV3 Drainage channels**	**1**	**3**	**3**	**3**	**2**	**1**	**2**	**3**	38	80	**14**
142	**XV4 Locally treated water streams**	**4**	**3**	**3**	**3**	**2**	**2**	**4**	**2**	48	130	**23**
143	**XM1 Wet ruderal fallow land**	**2**	**4**	**3**	**3**	**2**	**2**	**3**	**2**	44	108	**19**
144	**XR Degraded raised bogs**	**6**	**4**	**3**	**3**	**4**	**2**	**5**	**4**	65	240	**42**
145	**XS1 New stone and sand quarries**	**2**	**3**	**2**	**2**	**4**	**1**	**1**	**3**	38	81	**14**
146	**XS2 Supporting and dry walls**	**2**	**2**	**2**	**2**	**3**	**1**	**1**	**3**	33	64	**11**
147	**XS3 Tunnels**	**3**	**2**	**1**	**2**	**6**	**2**	**2**	**3**	44	104	**18**
148	**XS4 Landslides**	**3**	**4**	**2**	**2**	**4**	**3**	**1**	**3**	46	121	**21**
149	**XT1 Post-agrar fallow lands**	**2**	**2**	**3**	**4**	**2**	**2**	**2**	**3**	42	99	**17**
150	**XT2 Degraded wet wasteland**	**2**	**2**	**3**	**3**	**2**	**2**	**2**	**4**	42	100	**17**
151	**XT3 Intensively managed and degraded mesic meadows**	**2**	**3**	**3**	**3**	**1**	**1**	**3**	**2**	38	77	**13**
152	**XT4 Degraded grasslands and heathlands**	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**3**	44	108	**19**
153	**XT5 Plants of railway or road embankments**	**2**	**3**	**3**	**3**	**2**	**1**	**2**	**3**	40	88	**15**
154	**XT6 New mining areas and spoil heaps**	**2**	**2**	**2**	**2**	**4**	**1**	**1**	**3**	35	72	**13**
155	**XK1 Extensively managed or fallow wineyeards and orchards**	**3**	**3**	**3**	**5**	**4**	**3**	**3**	**5**	60	210	**36**
156	**XK2 Fallow land with bushes amd trees**	**3**	**4**	**4**	**3**	**4**	**2**	**2**	**2**	50	140	**24**
157	**XK3 Trees of railway or road embankments**	**3**	**3**	**3**	**3**	**2**	**1**	**2**	**3**	42	96	**17**
158	**XK4 Pioneering vegatation of athropogenic areas**	**2**	**3**	**4**	**3**	**2**	**1**	**1**	**2**	38	72	**13**
159	**XL1 Hedgerows and alleys**	**3**	**3**	**4**	**3**	**2**	**1**	**4**	**4**	50	143	**25**

160	**XL2 Lone trees**	**3**	**3**	**4**	**3**	**2**	**1**	**4**	**4**	50	143	**25**
161	**XL3 Monocultures of unappropriate tree species Hedges**	**2**	**4**	**3**	**4**	**3**	**1**	**3**	**2**	46	117	**20**
162	**XL4 Degraded forests with ruderal vegetation**	**2**	**4**	**5**	**3**	**1**	**2**	**3**	**2**	46	112	**19**
163	**XL5 Glades, forest plants and restoration forest planting**	**2**	**3**	**3**	**3**	**2**	**2**	**2**	**3**	42	99	**17**
164	**X1.1 New artificial water basins from natural materials**	**2**	**2**	**1**	**2**	**2**	**2**	**1**	**2**	29	49	**9**
165	**X1.2 Water reservoirs from concrete**	**1**	**1**	**1**	**2**	**2**	**1**	**1**	**3**	25	35	**6**
166	**X1.3 Technically treated rivers**	**2**	**2**	**1**	**2**	**2**	**1**	**2**	**1**	27	42	**7**
167	**X1.4 Polluted waters**	**1**	**2**	**2**	**2**	**1**	**1**	**1**	**2**	25	35	**6**
168	**X2 Technically treated springs, emptied or drained bogs without vegetation**	**2**	**2**	**2**	**2**	**6**	**1**	**1**	**3**	40	88	**15**
169	**X3.1 Ruins**	**1**	**3**	**3**	**3**	**4**	**1**	**1**	**3**	40	90	**16**
170	**X3.2 Used adits, tunnels and cellars**	**1**	**1**	**1**	**1**	**2**	**1**	**1**	**3**	23	28	**5**
171	**X4.1 Traditional village square**	**2**	**2**	**3**	**3**	**6**	**2**	**1**	**5**	50	140	**24**
172	**X4.2 Biotopes of one-year fallows**	**1**	**2**	**2**	**2**	**3**	**2**	**3**	**4**	40	84	**15**
173	**X4.3 Perennial plants on arable land**	**1**	**2**	**2**	**2**	**1**	**1**	**3**	**3**	31	56	**10**
174	**X4.4 One-year and autumn plants on arable land**	**1**	**2**	**2**	**2**	**1**	**1**	**3**	**3**	31	56	**10**
175	**X4.5 Herbaceous veget. on degraded areas, unrecultivted waste dumps**	**1**	**1**	**3**	**2**	**3**	**1**	**2**	**2**	31	56	**10**
176	**X4.6 Railway stations**	**1**	**1**	**2**	**1**	**3**	**1**	**2**	**3**	29	45	**8**
177	**X4.7 Wasteland in industrial, deposital and technical-agricultural areas**	**1**	**2**	**2**	**2**	**1**	**1**	**1**	**2**	25	35	**6**
178	**X5.1 Hedges**	**2**	**2**	**3**	**2**	**2**	**1**	**2**	**3**	35	72	**13**
179	**X5.2 Biotopes of vegetable gardens**	**1**	**2**	**3**	**3**	**2**	**1**	**3**	**3**	37	81	**14**
180	**X5.3 Intensively managed wineyeards, hop-fields and orchards**	**1**	**2**	**2**	**2**	**4**	**1**	**3**	**3**	37	77	**13**
181	**X6.1 Parks and gardens**	**2**	**3**	**5**	**3**	**2**	**1**	**2**	**3**	44	104	**18**
182	**X6.2 Graveyards and cemeteries with mainly allochthonous species**	**1**	**2**	**5**	**3**	**2**	**1**	**2**	**3**	40	88	**15**
183	**X6.3 Nurseries, forest plantations**	**1**	**2**	**2**	**3**	**4**	**1**	**1**	**3**	35	72	**13**
184	**X6.4 Monocultures of allochthonous tree species (e.g. false acacia)**	**1**	**2**	**3**	**2**	**3**	**1**	**1**	**2**	31	56	**10**
185	**XX1.1 Sedimentation basins, sewage treatment plants**	-	-	-	-	-	-	-	-	-	-	**0**
186	**XX1.2 Chemically devaluated water areas**	-	-	-	-	-	-	-	-	-	-	**0**
187	**XX1.3 Riverbeds from concrete (channels, tubes)**	-	-	-	-	-	-	-	-	-	-	**0**
188	**XX2 Chemically devaluated wetlands**	-	-	-	-	-	-	-	-	-	-	**0**
189	**XX3.1 Completely build up area with minimum vegetation**	-	-	-	-	-	-	-	-	-	-	**0**
190	**XX3.2 Impermeable surfaces and surfaces permanently without vegetation**	-	-	-	-	-	-	-	-	-	-	**0**
191	**XX4.1 Industrial and storage objects, waste dumps in intravillan**	-	-	-	-	-	-	-	-	-	-	**0**
192	**XX4.2 Impermeable surface** (tarmac, makadam and concrete surface of roads and parking places, technical areas, airports, bridges, dams…)	-	-	-	-	-	-	-	-	-	-	**0**

National restoration costs of one point were estimated in the Czech Republic on the basis of a statistically significant sample of real biotope restoration projects that represented all types of revitalisation activities. Approximately 140 projects have been analysed that had already been implemented over the last decade in different parts of the Czech Republic and which have brought and would bring the increase of point value of the restored area in the long run. The financial value of one point was counted for one revitalisation project as a sum of its costs divided by a sum of the point increase expected in the long-term future (in 2003 one point value was CZK 12.36, €0.388). In 2013, the average value of one point in the Czech Republic was set at CZK 15.88 (€0.61).

4.6 Energy-water-vegetation-based method for valuation of ecosystem services

In the period 2007-2009, our research team was given a new opportunity to elaborate the second dimension of ecological values of the Czech landscape – values of ecosystem services (Sejak et al., 2010). Energy-water-vegetation-based (EWV) environmental accounting represents an ecological approach to estimate the non-market value of ecosystem services. This EWV approach draws on the Energy-Transport-Reaction (***ETR***) model (Ripl, 1995, 2003) and estimates the main forms of **benefits** that nature and her autotrophic ecosystems provide in the form of delivering ecosystem services for society (air-conditioning service, water retention service, oxygen production service, sustaining biodiversity, etc.).

By the substitute cost method (sometimes called also replacement costs, avoided costs) in combination with the biotope valuation method, we obtained minimal values of annual ecosystem services for selected natural ecosystems that have not been valued up to now. As can be seen below, from the viewpoint of thermodynamics the dominant role is played by ecosystem air-conditioning (climatizing) and water retention services that, within the ecosystem self-organizing processes and according to real monitored data of energy-material flows, tend to be maximized with climax vegetation.

For a **deciduous forest ecosystem** saturated with water, the pilot estimations of services (estimated by replacement value approach and biotope valuation method) are as follows:

1. **Biodiversity:** L2.3 Hardwood forests of lowland rivers are valued according to the BVM at 66 points per 1 m^2, which for 1 ha means 660,000 points x CZK 12.36 per point = CZK 8,157,600 of stock value. With a 5% discount rate, this means annual service at the level **€ 16,320**

2. **Estimation of forest oxygen production:** In the temperate zone, 1 ha of deciduous forest produces annually around 10 tons of biomass (expressed in dry mass). This corresponds to the release of 10.6 tons of oxygen. Production of oxygen has been calculated from the fundamental equation of photosynthesis where formation of one molecule of 6-carbon sugar is associated with the release of 6 molecules of oxygen, i.e. the formation of 180 grams of sugar (cellulose etc.) is associated with the release of 192 grams of oxygen. From this stoichiometry it follows that the production of 10 metric tons of dry mass (wood) is accompanied by the release of 10.6 metric tons of oxygen. According to Avogadro's law, one gram-molecule of gas under normal atmospheric pressure and at a temperature of 20°C has a volume of 22.4 litres, i.e. 32 grams of oxygen take up 22.4 litres. Thus, the mass of 1 litre of oxygen is 1.429 g, or 1kg of oxygen has a volume of 700 litres.
   10,600 kg/ha x 700 litres = 7.42 mil. litres x € 0.02 per litre (oxygen price) = € 148,400

3. **Forest climatizing (air-conditioning) service:** In the temperate zone, 1 ha of deciduous forest transpires around 600 litres of water from 1m^2 during the vegetation season. 1 m^2 of forest saturated with water evaporates around 5 litres of water during a sunny day. Whereas photosynthesis (biomass production) uses less than 1% of the incoming solar energy, by evapotranspiration (latent heat) around 80 % can be used in water saturated vegetation. The latent heat of 1 litre of water is equal to c. 0.7kWh. It is necessary to emphasize the double air-conditioning effect of evapotranspiration: first, a tree cools itself and its environment by evaporation of water (solar energy is used as latent heat), second, water vapour condenses on cool surfaces (or in cool air) and releases latent heat. Considering the double air-conditioning effect (cooling during evapotranspiration and warming during water vapour condensation), annual climatizing service of 1 ha can thus be estimated
   600 l x 1.4 kWh (0.7 kWh cooling, 0.7 kWh warming) x 10,000 x €0.08 (electricity cost price) = € 672,000

4. **Support of short water cycles and water retention services:** evapotranspiration of 600 litres/m^2 brings an annual service: (600 litres/m^2) x € 0.114 (distilled water price) x 10,000 m^2 **€ 684,000**

Total annual services from 1 ha forest € 1,520,720

Summarizing the main annual ecosystem service values of 1 ha of river floodplain (Eiseltova et al., 2007):

1. **Flood control services:** investment costs for the retention of 1 m^3 of water by a man-made pond, in the Czech Republic, is CZK 100 (approx. 4 euro). For 1 ha of floodplain with a flood control capacity of 5,000 m^3, this makes for capital costs of CZK 0.5 million, which provides annual services (using a 5% discount rate) of **€ 1,000**
2. **Biomass production**: 5 tonnes annually x 4 MWh (=4,000 kWh) x € 0.08/kWh (electricity cost price) x 0.5 (efficiency) **€ 800**
3. **Nutrient retention:** 1 tonne of base cations and nutrients compared to drained arable lands = 1,000 kg x CZK 30-40 (€ 1.4 = price of 1 kg fertilizers) **€ 1,400**
4. **Biodiversity:** Alluvial *Alopecurus* meadows T 1.4 are valued (Sejak, 2003) at 46 points per 1 m^2, per 1 ha, which means 460,000 points x € 0.4944/point = € 227,424 of capital value; with a 5% discount rate, the annual value of service is **€ 1,370**
5. **Oxygen production:** 3.5 mil. litres O_2 x CZK 0.25-0.73 per litre (CZK 0.50 = € 0.02) **€ 70,000**
6. **Climatizing service:** A modest estimate is 500 litres of evapotranspired water from 1m^2 during the vegetation season. Annual climatizing service of 1 ha can thus be estimated as 500 x 1.4 kWh (0.7 kWh cooling, 0.7 kWh warming) x 10,000 x €0.08 (electricity cost price) **€ 560,000**
7. **Support of short water cycles, water retention services:** evapotranspiration of 500 litres of water per one m^2 brings an annual service of: (500 litres/m^2) x € 0.114 (1 litre distil. water price) x 10,000 m^2 **€ 570,000**

Total annual services from 1 ha floodplain **€ 1,214,570**

If a natural landscape is drained, as the following account of **drained foothill pasture** (channel straightening and recessing) shows, its ecosystem services substantially decline:

1. Biomass production: 5 tonnes annually x 4 MWh (=4,000 kWh) x € 0.08 x 0.5 **€ 800**
2. Biodiversity: Intensively managed or degraded mesic meadows X T.3 are valued (Sejak 2003) at 13 points per 1 m^2; per 1 ha this means 130,000 points x € 0.4944/point = € 64,272 of capital value; with a 5% discount rate, the value of annual services is **€ 3,200**
3. Oxygen production: 2.8 mil. litres O_2 x CZK 0.25-0.73 per litre (CZK 0.50 = € 0.02) **€ 56,000**
4. Climatizing services: Around 300 litres of evapotranspired water from 1m^2 during vegetation season. Annual climatizing service of 1 ha can thus be estimated 300 x 1.4 kWh (0.7 kWh cooling, 0.7 kWh warming) x 10,000 x €0.08 (electricity cost price) **€ 336,000**
5. Support of short water cycles and water retention services: evapotraspiration of 30 m^3 of water per 1 ha on a sunny day brings an annual service: (300 litres/m^2) x € 0.114 (destil. water price) x 10,000 m^2 **€ 342,000**

Total annual services from 1 ha of drained pasture **€ 738,000**

Note that not only does a drained landscape waste the precipitated water—it usually also demands external inputs of energy for the production of biomass.

National scale

For the nation-wide estimations of ecosystem functions and services, the four financially most important services were selected: biodiversity service based on the BVM annual values, production of oxygen, climatizing service, and short water cycle.

22 Biotope Groups in the Czech Republic According to Their Provision of four ES

No.	Biotope groups	Area	Ecosystem services (€/m2/year)				Total of four ES	
		km2	Climate regul. s.	Short Water Cycle	02 production	BD	Relat. value €/m2/year	Total value billion €/year
1	Water bodies, courses	675	67	57	25	0.5	150	101
2	Peatbogs	23	90	74	3	1.5	168	4
3	Other wetlands	364	90	74	30	1	195	71
4	Ext. used mesic pastures meadows	2601	67	34	16	1.2	118	308
5	Intens. used mesic pastures meadows	5579	56	34	21	0.3	111	623
6	Degraded mesic pastures meadows	4609	45	20	12	0.3	77	355
7	Dry closed grasslands	40	45	11	11	1.2	68	3
8	Dry interspaced grasslands	172	33	9	6	1.2	49	9
9	Xeric scrub	426	45	17	12	0.8	75	32
10	Mesic scrub	1959	56	34	16	0.8	107	209
11	Alluvial hygrophilous scub	17	67	55	17	1.1	140	2
12	Dry pine forests	298	45	26	13	1.2	85	25
13	Other conifer forests	6050	56	46	23	1	126	761
14	Damaged conifer forests	8222	45	34	19	0.5	98	807
15	Leafy forests	6636	78	69	27	1.4	175	1160
16	Leafy forests degraded	1632	56	40	19	0.6	115	189
17	Alluvial flooded forests	924	90	80	30	1.5	201	186
18	Solitary trees, alleys	1276	56	34	21	0.6	112	143
19	Arable land: cereal, root-crops	27605	33	9	13	0.2	55	1541
20	Arable land: fodder, durable stands	141	45	20	30	0.2	95	13
21	Areas without vegetation	2938	11	3	0	0	14	41
22	Rock biotopes	113	23	11	3	1.2	38	4
23	Other (semi) natural biotopes	3780	66	50	22	1	140	528
24	Other anthropically influenc. biotopes	2787	38	17	14	0.3	70	196
	Czech Rep. total	**78869**						**7310**

Clim. s.= climate-regulation service, expressed by litres of evapotranspired and condensed water, double air-conditioning effect (evapotranspiration and cooling effect,condensation and warming effect, both latent heat changes of 1 litre of water=1.4 kWh); l/m2/year x €0.08 (electricity cost price).
SWC=water retention service of the short water cycle; l/m2/year x €0.114 (cost price of 1 litre of distilled water).
O_2 production= O_2 (kg/m2/year) x 700 (kg changed to litres) x €0.02 (cost price of 1 litre of oxygen).
BD=habitat provision service (valued by biotope valuation method; Sejak et al., 2003).
Source: Sejak et al. (2010); Exchange rate €=CZK 25

Value maps follow.

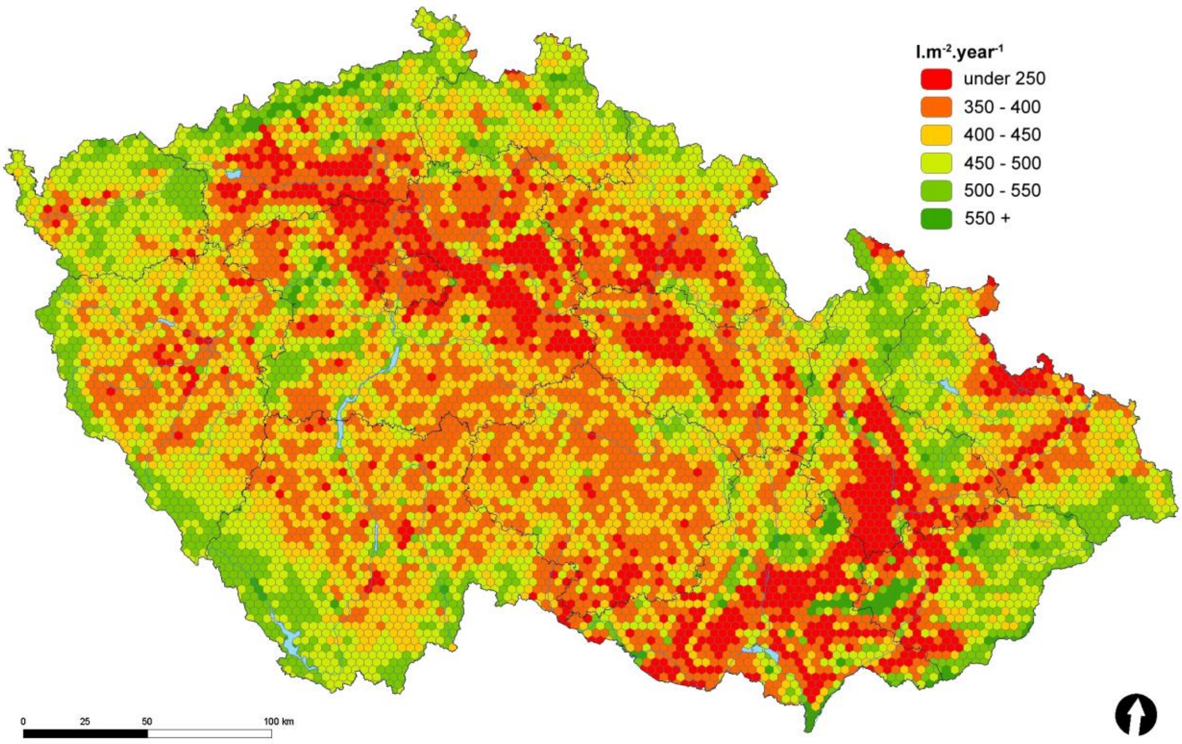

Fig. 4.2 Climatizing (air-conditioning) function of biotope groups in the CR (CLC maps 2000).

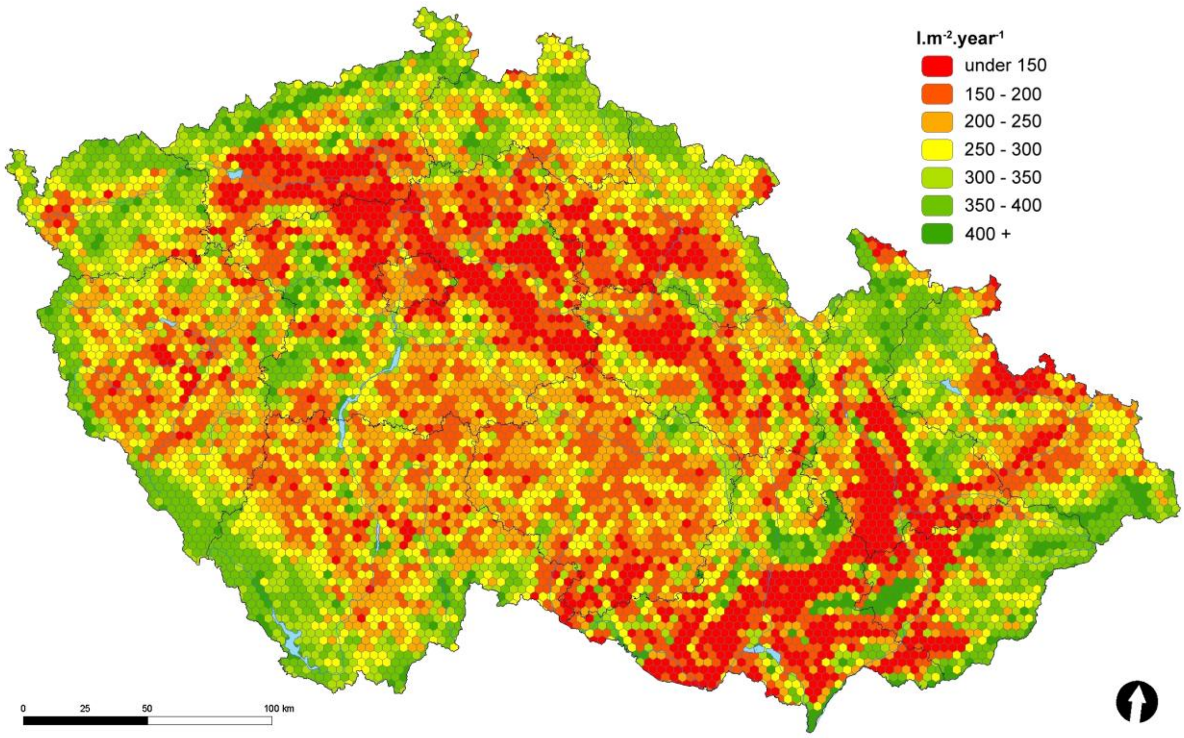

Fig. 4.3 Map of short water cycle of groups of biotopes in the CR (CLC maps 2000).

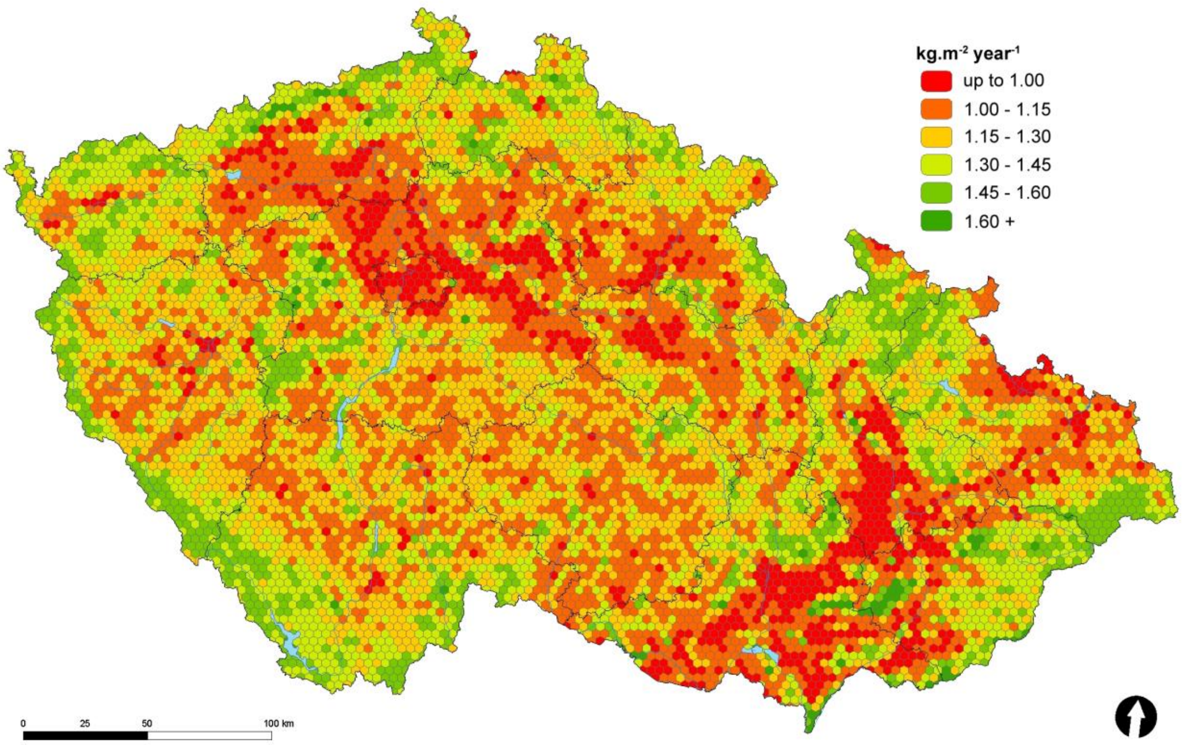

Fig. 4.4 Map of oxygen production by different biotope groups (Corine-LC 2000).

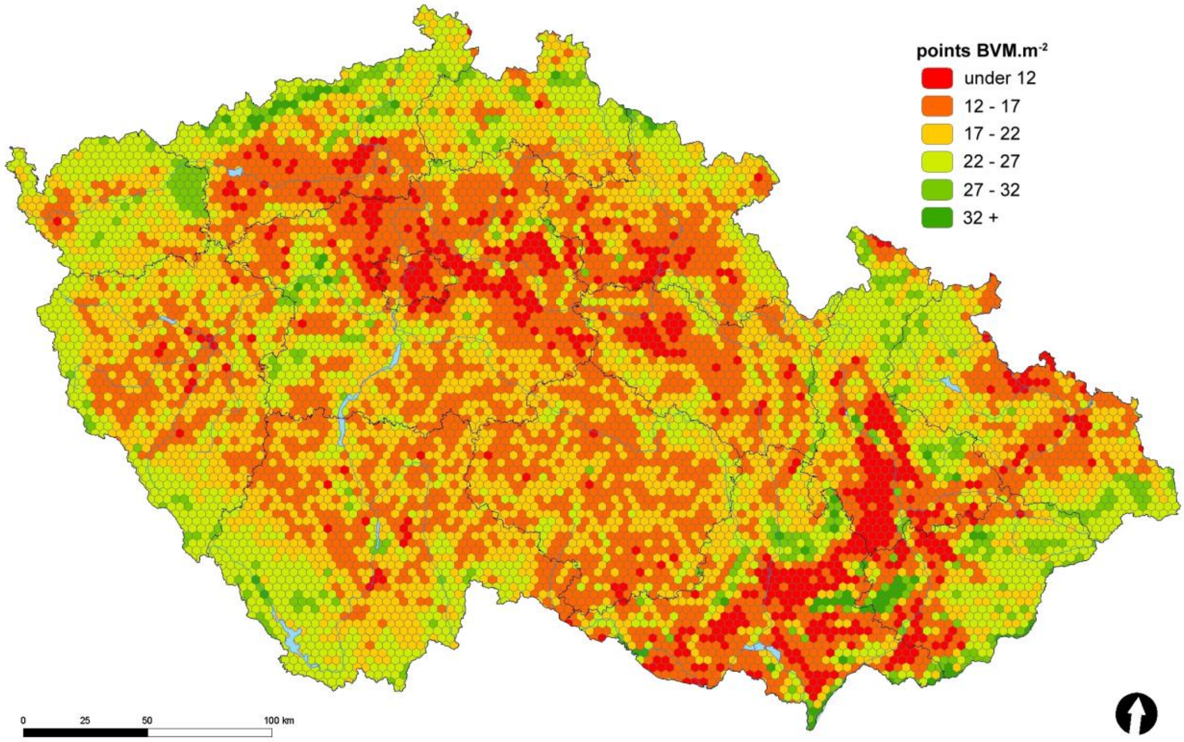

Fig. 4.5 Map of biotope types point values (Corine-LC 2000.)

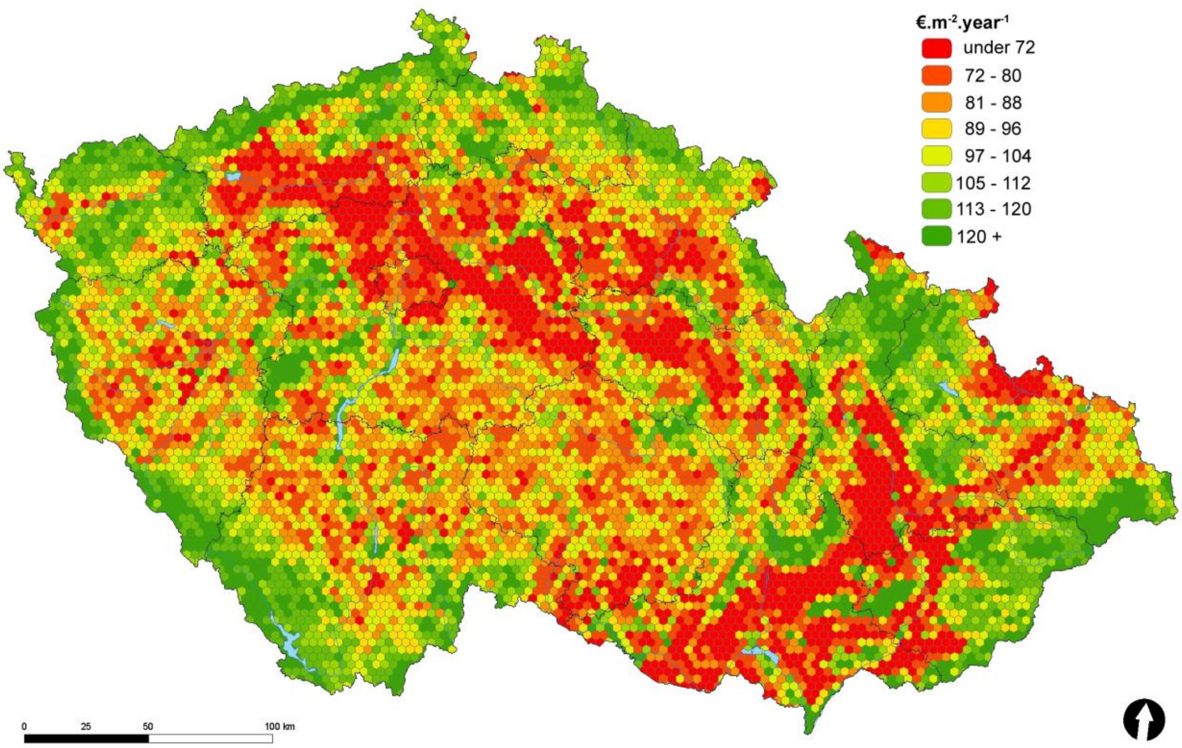

Fig. 4.6 Map of four ecosystem services' monetary values (climatizing service, short water cycle, oxygen production, biodiversity service) in CZK.m^{-2}.$year^{-1}$ based on CLC 2000.

Comparing 4ES efforts: agregated biotope groups

CR=78 869 km², 4ES in total= 182 743 bln. CZK/year, GDP 3689 bln. CZK

Arable, anthrop.land	km²	4 ES, CZK billion	CZK/m2/year
arable: grain, root-crops	27605	38535	1396
arable: fodder, peren. plant	141	334	2363
Other anthrop. Infl. land	2787	4896	
Σ	30533	43765	
Share in national sum	**0.39**	**0.24**	**(0.6)**

Grasslands	km²	4 ES, CZK billion	CZK/m2/year
Extens. used mesophilic meadow, pastures	2601	7690	2957
Intens. used mesophilic meadow, pastures	5579	15517	2781
Degraded used mesophilic meadow, pastures	4609	8868	1924
Dry closed grasslands	40	68	1698
Dry interspaced grasslands	172	213	1235
Σ	13001	32356	
Share in national sum	**0.165**	**0.177**	**(1.07)**

Forests, scrub	km²	4 ES, CZK billion	CZK/m2/year
Xeric scrub	426	796	1865
Mesophilic scrub	1959	5232	2671
Alluvial hydrophilic scrub	17	58	3496
Dry pine forests	298	633	2128
Other conifer forests	6050	19031	3146
Damaged conifer forests	8222	20168	2453
Leafy forests	6636	29015	4372
Leafy forests degraded	1632	4717	2891
Alluvial flooded forests	924	4648	5032
Solitary trees, alleys	1276	3577	2802
Other natural biotopes	3780	13211	3495
Σ	31220	101086	
Share in national sum	**0.40**	**0.55**	**(1.4)**

Waters, wetlands	km²	4 ES, CZK billion	CZK/m2/year
Water bodies, courses	675	2524	3740
Wetlands, peatbogs	387	1873	4878
Share in national sum	**0.013**	**0.024**	**(1.8)**

Rest of national territory (4%) covered by antropogenically changed areas with minimal ES efforts

The following table presents an overview of biotope, ecosystem service and economic capital values for the territory of the Czech Republic. Please note the diametrical contradictions in how people value the territory (economic values, pushed up by draining the surfaces) and how ecosystems (working in the synergy of solar energy fluxes, vegetation and water cycles) escalate the values of biotopes (BVM) and mainly values of life-supporting services (ecosystem service values) when left to develop naturally on their own, gradually becoming saturated by water and vegetation.

Table 4.2 Biotope capital values, ecosystem service (ES) annual values, ecosystem service capital values and official prices of 1 m^2 of the Czech territories in €*

(biotope capital values estimated by the BVM, ecosystem services capital value by a 5% discount rate, official prices ordered by the Czech Min. of Finance, Decree no. 441/2013) **Values in €/m^2**

LAND COVER 1:100000	Biotope values	Annual ES values	ES capital values	Official prices	Notes
1.1.1. Continuous urban fabric	0 - 1.20	27	535	1.4 - 90	acc. to urban size
1.1.2. Discontinuous urban fabric	5.04	78	1557	1.4 - 90	acc. to urban size
1.2.1. Industrial or commercial units	0 - 1.32	32	638	1.4 - 90	acc. to urban size
1.2.2. Road and rail networks and assoc. land	4.00	58	1156	1.4 - 90	acc. to urban size
1.2.3. Port areas	3.92	70	1398	1.4 - 90	acc. to urban size
1.2.4. Airports	5.92	80	1591	1.4 - 90	acc. to urban size
1.3.1. Mineral extraction sites	6.64	43	864	1.4 - 90	acc. to urban size
1.3.2. Dump sites	3.88	99	1981	0.04	
1.3.3. Construction sites	3.52	42	844	1.4 - 90	acc. to urban size
1.4.1. Green urban areas	9.52	106	2127	1.4 - 33	
1.4.2. Sport and leisure facilities	9.28	79	1589	0.4 - 0.6	
2.1.1. Non-irrigated arable land	5.12	62	1242	0.04 - 0.7	acc. to soil quality
2.2.1. Vineyards	7.52	88	1769	0.04 - 6.4	
2.2.2. Fruit trees and berry plantations	7.00	88	1764	0.04 - 4	

2.3.1. Pastures	10.28	102	2050	0.04 - 0.4	ann. ES €75 m^{-2}
2.4.2. Complex cultivation	6.96	85	1696	0.04 - 0.4	acc. to soil quality
2.4.3. Land with agricult.& natural vegetation	10.64	100	1996	0.04 - 0.4	acc. to soil quality
3.1.1. Broad-leaved forest	20.12	156	3118	0.1 - 4.4	
3.1.2. Coniferous forest	12.96	124	2490	0.1 - 4.4	
3.1.3. Mixed forest	14.08	131	2616	0.1 - 4.4	
3.2.1. Natural grassland	16.32	109	2177	0.04	
3.2.2. Moors and heathland	26.20	129	2576	0.04	
3.2.4. Transitional woodland shrub	11.64	106	2128	0.04	
3.3.2. Bare rock	19.68	107	2144	0.04	
4.1.1. Inland marshes	16.56	159	3174	0.04	
4.1.2.Peatbogs	26.36	168	3361	0.04	
5.1.1. Water courses	11.44	139	2776	0.4	
5.1.2. Water bodies	9.24	148	2962	0.4	

* Exch. rate: € 1 = CZK 25

According to our estimations, the total amount of annual ecosystem services on the territory of the Czech Republic is at the level of CZK 182 trillions ($182x10^{12}$). Compared to the annual GDP in 2008 ($3689x10^{9}$), four annual ecosystem services are fifty times bigger.

By utilizing these two methods (BVM, EWVM), two scales of ecological values of landscapes (both as flows and stocks) have been derived. Subsequently, these environmental values may be compared with market prices of standard land uses.

4.6.1. Results

Biosphere 1, i.e. the Planet Earth, produces all ecosystem services daily at no charge for nearly 7 billion people. If Biosphere 2 at the beginning of the 1990s needed a $200 million investment for eight people, then the natural capital of the global ecosystem could be estimated at least at the value level of $165 quadrillion ($165 \times 10^{15}$). Let us note that at the beginning of the 1990s, the world annual GDP of about 6.6 bln. people reached approximately USD 16 trillion (16×10^{12}), i.e. was ten thousand times lower than the estimated natural capital value of global biosphere.

If we transfer, similarly as Costanza et al. (1997, p. 258), the dimension of natural capital stock into a dimension of annual flow of world ecosystem services (using a 5% discount rate) then the annual value of world ecosystem services would be USD 8 quadrillion (8×10^{15}), which means five hundred times higher than the annual world GDP. From this single example it is clear that the estimations of world natural capital, based on substitute costs method, are at the level much higher than the world GDP.

Comparing the composition of our results of valuing ecosystem services in Table 2 with the results of Costanza et al. (1997), we can easily identify that in our energy-water-vegetation based approach, the predominant services consist of climate regulation, generated synergically by solar energy dissipative processes through vegetation and water, i.e. through evapotraspiration, while in Costanza et al. around 51 % of total value is created by the nutrient cycling service (Costanza et al., 1997, p. 256). In our approach, solar energy dissipative processes dominate and, as temperature, precipitation and water purification regulating services, create around 90 % of total services value in natural ecosystems (if valued by man-made abilities to replace or substitute for these natural life-supporting processes of the biosphere). If one item in this natural triple-part self-organizing processes is reduced by humans, as in the case of drained foothill pasture, the level of ecosystem services substantially declines. In the Costanza et al. estimates, the climate regulating services (temperature and precipitation) create no more than 2 % of ecosystem services total value (valued by demand-curve approaches, i.e. by summing individuals' willingness to pay for such services). This comparison shows that for the most decisive life-supporting services of the biosphere, the majority of human individuals still have very weak preferences (that up to now converge to nearly zero) even though from the viewpoint of solar energy throughput and high effectiveness of its use by joint efforts of vegetation and water, these life-supporting services can only partly and very expensively be substituted by man-made technologies.

4.6.2 Conclusions

Biosphere 2 was the first human experiment striving to replace or to emulate completely all the Earth's biosphere functions and services in the man-made environment of a sealed air-tight greenhouse, where eight researchers together with many other species tried to survive for two years. No wonder that the project costs of annual ecosystem functions and services per one person reached up to 500 times the average world annual GDP per capita and the natural capital of Biosphere 2 soared to around 10,000 times the average world annual GDP per capita.

Our pilot estimate of annual ecosystem service values in the CR represents only four elements out of the complete set of functions and services of national ecosystems. Therefore, our estimate is approximately one order of magnitude lower compared to Biosphere 2. In spite of this, the estimated **annual ecosystem services** in the Czech Republic **exceed the annual GDP fifty times**.

In any case, our results, obtained through the replacement cost method, show that the so-called supporting and regulating services of ecosystems (sometimes improperly called intermediary services) are of primary importance for maintaining the main existential conditions for current living species, but as indirect use values they have not yet entered into the ethical and decision-making framework of most humans.

It is not the replacement cost method that tends to overestimate actual values of supporting and regulating services of ecosystems, but rather the preference methods that expressively underestimate these primary services of nature. If viewed as complementary, these two methodological approaches show the range of ecosystem service values, from how people value these life-supporting services to their real abilities to replace them.

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Enclosure 1 Valuing damages and losses from the construction of Klanovice golf resort

A plan to construct a new golf resort in the full-grown forest in Prague-Klanovice was announced. Two alternatives were offered: Alternative 1: In this 18 hole course, within the site clearance 31 hectares of existing forest is supposed to be cut. Alternative 2a: for a 9 hole course 7.5 hectares of forest is proposed to be cut **(**M. Macháček, EKOEX Jihlava, http://tomcat.cenia.cz/eia/detail.jsp?view=eia_cr&id=MZP216). After a detailed digital analysis it is found that alternative 2a supposes to cut, instead of 7.5 hectares, 10.94 hectares of forest altogether.

Tab. 1. Areas of biotopes for planned golf course in two alternatives 1 and 2a

Alternative 1 - courses		Alternative 1 - touched area		Altern. 2a-courses		Altern. 2a–touched area	
biotope	area (m^2)	biotope	area (m^2)	biotope	area (m^2)	biotope	area (m^2)
L2.2B	141.4	L2.2B	7509.3	L2.2B	602.2	L2.2B	7509.3
L3.1	3407.0	L3.1	4651.5	L7.1	6947.3	L3.1	4651.5
L7.1	40286.3	L7.1	77172.7	L7.2	6133.8	L7.1	14115.8
L7.2	20921.7	L7.2	105773.1	T1.1	593.2	L7.2	95290.3
M1.7	3635.8	M1.1	54.9	XL3	95734.6	M1.1	54.9
T1.1	5195.2	M1.7	5433.6	XT3	588.0	M1.7	5433.6
V1F	215.6	T1.1	7797.7			T1.1	7797.7
XK4	4780.8	T1.10	426.2			T1.10	426.2
XL3	239100.1	V1F	7397.0			V1F	7397.0
XL5	8082.4	X11	1831.6			XK4	1.9
XT3	4403.4	XK4	6057.1			XL3	423408.9
		XL3	657665.9			XT3	10290.1
		XL5	1712.3			XX1.1	446.1
		XT3	10290.1				
		XX1.1	446.1				
Total	**330169.6**		**894219.2**		**110599.1**		**576823.4**

L2.2 Ash-alder alluvial forests, L3.1 Hercynian oak-hornbeam forests, L7.1 Dry acidophilous oak forests, L7.2 Wet acidophilous oak forests, M1.7 Tall-sedge beds, T1.1 Mesic *Arrhenatherum* meadows, V1 Macrophyte vegetation of naturally eutrophic and mesotrophic still waters, XK4 Pioneering vegetation of anthropogenic areas, XL3 Monocultures of unappropriate tree species, XL5 Glades, forest plants and restoration forest planting, XT3 Intensively managed and degraded mesic meadows; details of biotopes: http://fzp.ujep.cz/projekty/bvm/bvm.pdf

Results of applying the Biotope valuation method (Seják, Dejmal a kol. 2003)

Areas of the courses (where mineral fertilizers and biocids are applied) are valued as chemically touched areas with external water delivery by 9 points per m2 and greens by 5 points per m2. The constructed golf course (with artificial surface and artificial water regime) is treated as artificial biotope with zero ecosystem services.

Tab. 2. Damages on forest biotopes (without and with individual valuation)

	Alternative_1 - courses		Alternative_1 – touched areas	
	points	Value CZK	points	Value CZK
Without indiv.valuation	7562334	93470451	20289996.16	250784353
With indiv. valuation	8073767	**99791762**	21914899.54	270868158
After project realisation	2971526	**36728061**		
Biotope damage (without ind.v.)	4590808	**56742387**		
Biotope damage (with ind. v.)	5102241	**63063698**		
	Alternative_2a -courses		Alternative_2a – touched areas	
	points	Value CZK	points	Value CZK
Without indiv.valuation	2374061	29343400	13665746.91	168908632
With indiv. valuation	2666033	**32952176**	14816909.38	183137000
After project realisation	995392	**12303045**		
Biotope damage (without ind.v.)	1378669	**17040349**		
Biotope damage (with ind. v.)	1670641	**20649123**		

Table 2 shows that by realization of alternative 1, biotope damage would be generated at the level of CZK 56.7 mil., or after individual biotope valuation at the level of CZK 63 mil. Alternative 2a would generate CZK 17 mil. and after individual valuation CZK 20.6 mil.

Estimating damages on ecosystem services

1. Forest climate regulation service

Alternative 1

400 l/m^2 and year x 1.4 kWh x 10 000 x 2 CZK/kWh = CZK 11.2 mil. of annual service per 1 ha x 31.18 ha ≈ **CZK 349 mil**.

Alternative 2a

300 l/m^2 and year x 1,4 kWh x 10 000 x 2 CZK/kWh = CZK 8.4 mil. of annual service per 1 ha x 10.94 ha ≈ **CZK 92 mil**.

2. Damages on short water cycle

Alternative 1

(400 litres/m^2) x cca CZK 2.85 (price of litre of distil. water) x 10000 = CZK **11.4 mil.**

x 31.18 ha = 355.452 mil. Kč ≈ **CZK 355 mil.**

Alternative 2a

300 litres/m^2 x CZK 2.85 (price of litre of distil. water) x 10000 = CZK **8.55 mil.**

CZK 8.55 mil. annualy x 10.94 ha = CZK 93.537 mil. ≈ **CZK 94 mil.**

3. Estimate of the oxygen production service by the forest

Alternative 1

10 000 kg/ha x 31.18 ha x 700 litres x CZK 0.50/litre ≈ **CZK 109 mil.**

Alternative 2a

6 600 kg/ha x 10.94 ha x 700 litres x CZK 0.50/litre≈ **CZK 25 mil.**

In total:

By clearing 31 ha in alternative 1 or 10.9 ha in alternative 2a of a fully-grown forest, the Prague agglomeration will lose the total annual value of three ecosystem services

Alternative 1 CZK **813 mil.**

Alternative 2a CZK **211 mil.**

Conclusion:

Part of the touched area belongs among Sites of Community Importance called Blatov and Xaverovský háj. In accordance with act no. 167/2008 Coll., on prevention and remedying environmental damage, environmental authorities must refuse such project. If, in spite of that, the project is realized, environmental damages will be created by cutting the forest:

1. Investor must undertake complementary remediation by means of planting new forest at new Prague territory areas of 30.39 ha in alternative 1 or 10.94 ha in alternative 2a.
2. As interim losses on ecosystem services CZK 813 mil. in Alternative 1, or CZK 211 mil. in Alternative 2a should be paid (enclosure 4, act No. 167/2008 Sb., in the period of 30 years, which is half time of the real age of the existing forest.

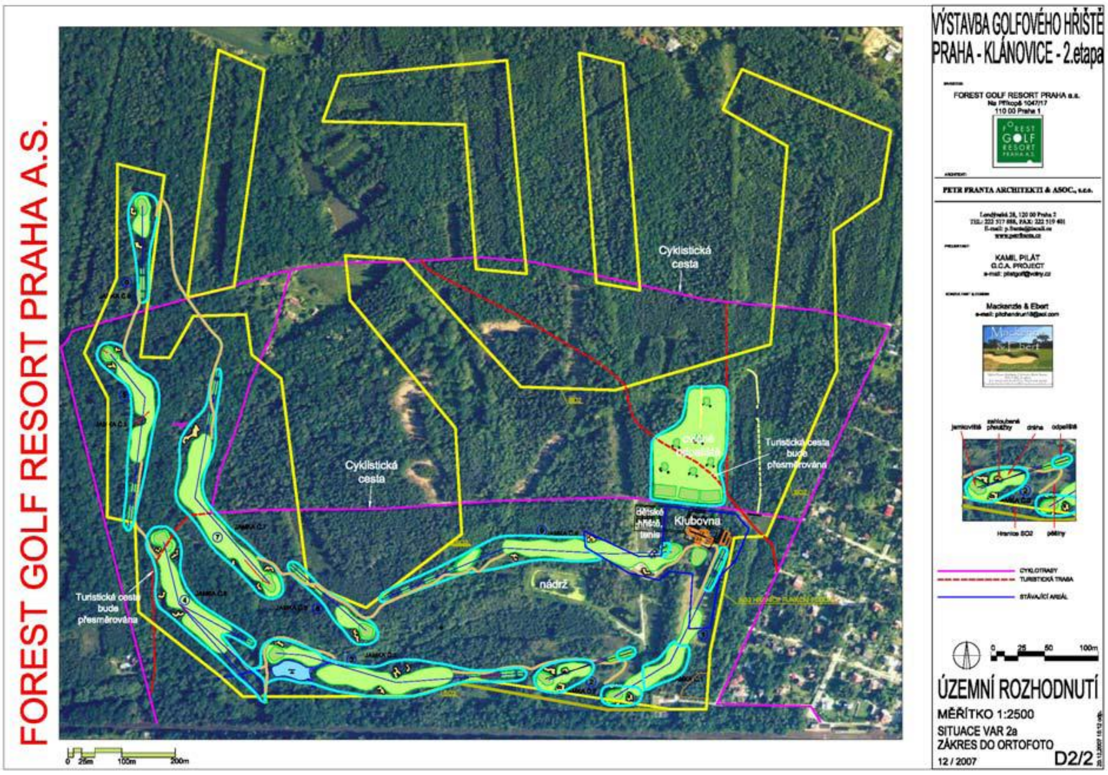


Fig. 1. Map for estimating Alternative 2a courses – indicated by blue line.

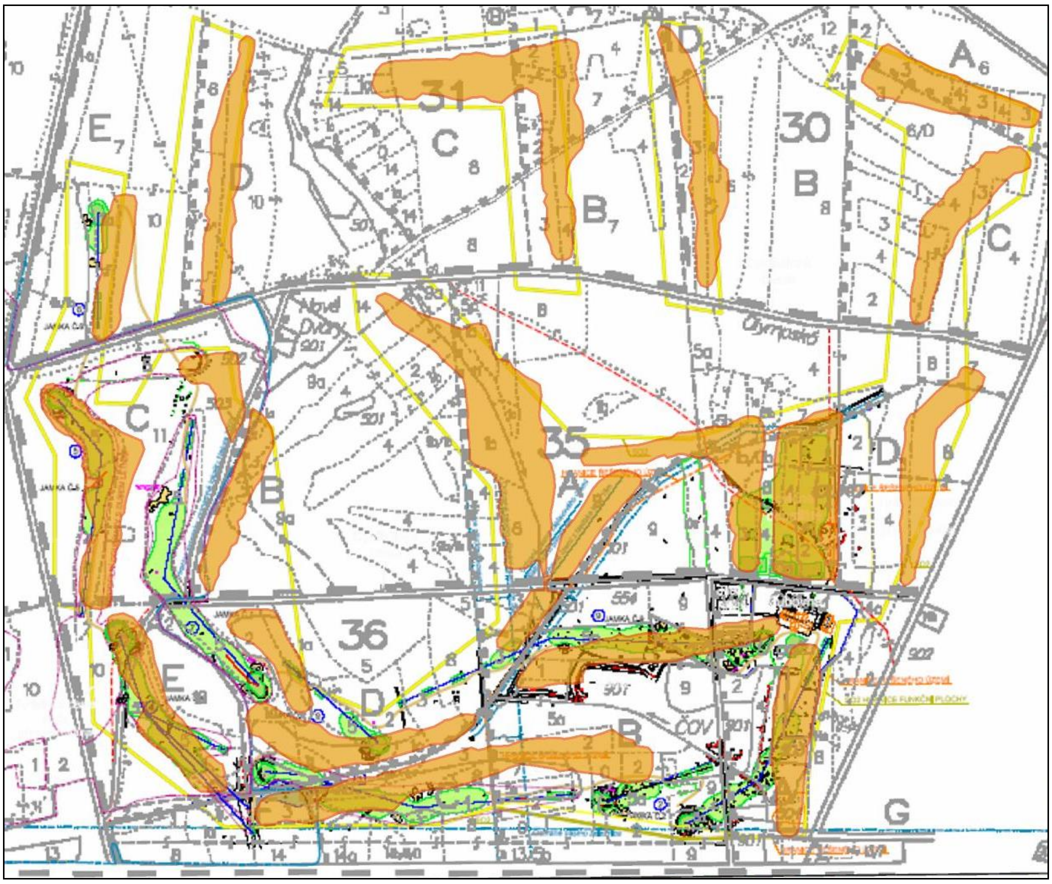
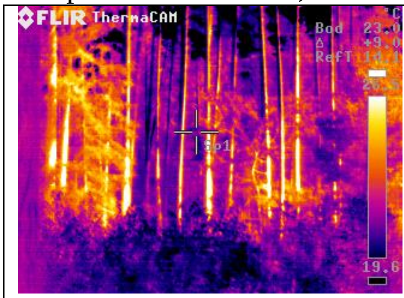


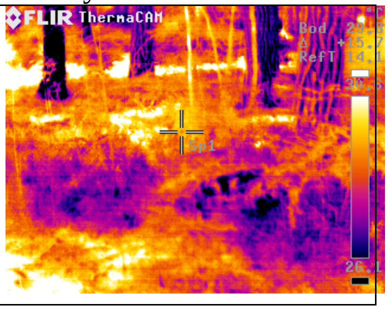
Fig. 2. Areas of Alternative 1 - areas of courses

Enclosure 2 Examples of thermocamera images from different biotopes

Thermovision images acquired on a clear-sky day (25th August 2009) around 13:00 GMT+1 show the temperature differences in biotopes.

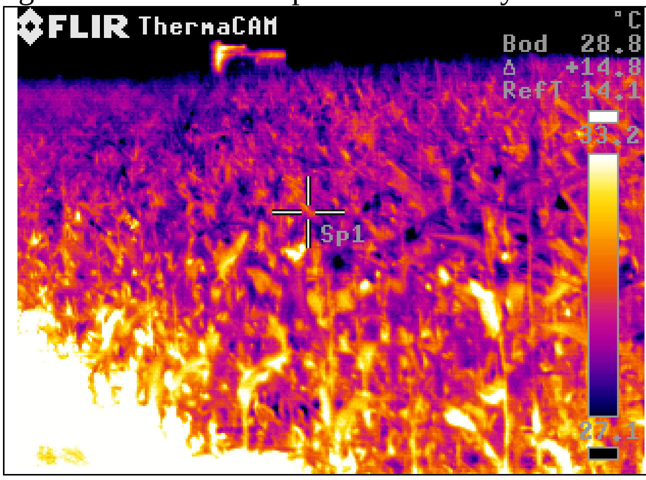
Full-grown pine forest. The temperature in the forest is around 20 ^{o}C, in the range of 4 ^{o}C. The vertical temperature distribution is remarkable. The temperature in the undergrowth is often lower than the temperature in the upper canopy. In the case of temperature inversion, humid air does not rise up from the stands and stays inside.



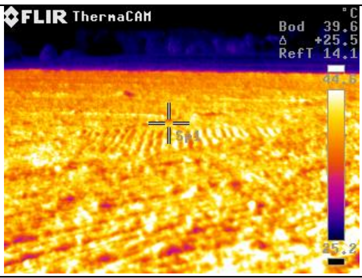



A stubble with a backdrop of trees in the background. The stubble temperature is about 40 °C. In the neighboring forest, the temperature is 20 degrees lower. Images in the forest and of the stubble were taken within a few minutes.


Corn field shows the temperature range of 27-33 °C; it is noteworthy that soil temperatures are sometimes higher than the surface temperature of the top of crop. The air then rises up the vegetation and water vapor is taken away.



The temperature of a plowed field can reach up to 44 °C.



A tree in the built-up areas has a canopy temperature of about 27 °C; in the shade of the tree the temperature is even lower. The surrounding roofs have a temperature above 40°C.

The effect of mesophilic meadow mowing is obvious from the difference of dry grass (35 °C) and non-mowed green grass (25 °C).