Chapter 1

Introductory Chapter: Evaluation Methods of Ecosystem Services and Their Scientific and Societal Importance in Service of Solving the Global Problems of the Humankind

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Additional information is available at the end of the chapter

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1. Introduction

Reduction of ecosystem services plays a key role in the group of phenomena that is called global ecological crisis. Population explosion has resulted in overpopulation of our planet. Energy source of this overpopulation has been fossil fuels (coal, mineral oil and natural gas) produced by the biosphere over millions of years during the history of the Earth. Exploiting and burning of these natural resources have decreased living conditions of subsequent generations and have started a global climate change at the same time. However, it is more important that urban areas and agricultural land have extended in place of natural ecosystems, causing them to decrease drastically and malfunction, which has resulted in a biodiversity crisis, mass species extinction. Besides these, the global ecological crisis includes industrial, agricultural, traffic and residential pollution, which have damaged abiotic components of habitats, that is, air, soil and water. Deteriorating ecological conditions have caused social problems directly and indirectly, such as epidemics, poverty and humanitarian crises. Besides these, pollutant and nature-destroying economic activities increase wealth and income inequality among people, which results in further social tensions (crime, terrorism, riots and wars). At the same time, problems are aggravated by favorable processes whose disadvantages are not considered at first. Increasing scientific research has led to an information explosion. Due to this, experts have been forced back to a more and more narrow intellectual space; our excellent scientific specialists are less and less able to have an overview of their own wider discipline and, especially, the whole science, and thus, they are less and less able to solve complex problems and avoid them if possible. In the database Web of Science, which is the collection of scientific articles of the highest level, there are only 224 articles with the expression "global problems" in their title (at the time of writing this text), whereas 59,957 articles can be found with Drosophila (name of a fruit fly) in their title. Thus, researchers prefer more than 250 times dealing with molecular effects of any gene of a tiny fly to the complex study of the burning problems of our time. Of course not the scientific research is the only source of our knowledge, but the global usability of local ecological knowledge also depends on scientific and social science research [1, 2]. Not even the scientific world is dealing with solving the global ecological crisis; however, it might be even graver that if scientists presented suitable solutions, there would be currently nobody to execute them. Mankind is struggling not only with overpopulation crisis, environmental crisis, biodiversity crisis, social crisis and information crisis but lacks global coordination as well, which would be essential for political guidance. Mankind does not have a central legislative and executive power necessary for saving the whole Earth, but decision-making processes are split up among 195 nation states, among which the probability of substantial consensus approaches zero even in the most important questions.

Land cover change research has an important role in understanding the intensity and dynamics of real global processes [3–7]. The Land-Cover and Land-Use Change (LCLUC) Program launched by the National Aeronautics and Space Administration (NASA) is studying natural and human-induced changes of the vegetation of the Earth and consequences of environment transformation processes and attempts to forecast natural disasters considering the Earth as a single complete system, with the help of satellite images, using the tools of NASA and combining them with laboratory and modeling work [8].

Survival of mankind and sustainability of the society depend on ecosystem services provided by natural ecosystems. Only a healthy biosphere is able to regulate the climate of the Earth and keep it in a range suitable for us.

1.1. Ecosystem services

Goods which mankind receives from the natural environment, from properly functioning ecosystems are called ecosystem services. These goods contribute to the survival and well-being of people directly or indirectly. Ecosystem services can be divided into four different groups [9].

Provisioning services: food, biofuels, genetic diversity, medicinal plants (natural pharmaceuticals), ornamental materials.
Regulating services: climate regulation, water purification, river regulation, erosion prevention, pollination.
Supporting services: water and nutrient cycling, photosynthesis and primary production, soil formation (pedogenesis).
Cultural services: spiritual and religious enrichment, esthetic values, recreation and tourism.

Value of ecosystem services can be expressed in money, which indicates preferences of the users and helps to determine how much resource to expend in order to maintain or restore an ecosystem [10]. Protection of intact ecosystems helps to increase resilience against adverse effects of climate change [11]. Biodiversity, that is, diversity of life maintains and restores services.

Ecosystems have certain resilience, of course; however, their ability to provide services to mankind is decreasing due to harmful human activities. This is caused by the fact that ecosystem services are less known or their importance is underestimated in political decisions [12]. They are so essential for life that people consider their existence as evident, and it is difficult to imagine that mankind can destroy these as well [13]. Ecosystem services affect each other and connect to each other in a rather complex way, and if humans use one of the services, they affect the others too [14]. For example, if the maximum yield is aimed for with intensive agriculture, this has a negative effect on the water and nutrient cycling of the area. In recent decades, the most important changes in ecosystem services have been caused by a continuous decrease in the area of intact ecosystems [15]. Between 1997 and 2011, a damage of 4.3–20.2 trillion USD was created globally due to the fact that the area of intact, properly functioning ecosystems was decreasing, and they were replaced by artificial ecosystems [16]. Urbanization is increasing, more and more people live in cities in the world. Where the soil is not covered by asphalt and concrete, plants and animals may appear and ecosystems may form. These can be alleys along the roads, parks, artificial creeks and lakes as well as gardens. Ecosystem services are present here as well, which influence people's life positively. For example, removing dust from the air, microclimate regulation and providing more attractive environment for residents [17].

2. Evaluation methods of ecosystem services

Experts more and more often encounter the problem that the value of a certain area, ecosystem or species has to be estimated. They have to decide how to handle a certain area and what to do with plants and animals, for example, whether a forest has to be left in its natural state or has to be cultivated. In this case, the value of that forest has to be estimated. In the academic literature, there are two approaches regarding the value estimation of natural ecosystems, the anthropocentric and the biocentric one. According to the first one, anything in nature can be as valuable as it benefits mankind. However, according to the second approach, everything in nature has an inner value, independently from its benefits for mankind [18]. Supporters of the anthropocentric approach mean that since humans are the dominant species on the Earth, they have the right to determine the value of anything [18]. According to the other approach, nature has direct (use) and indirect (nonuse) values [19]. According to the Millennium Ecosystem Assessment, goods provided by nature can be divided into four categories: provisioning services (e.g., fishing, timber), regulating services (e.g., climate and flood regulation), supporting services (e.g., pollination, pest control) and cultural services (e.g., tranquility, inspiration) [20]. Since the 1960s, more and more attention is paid to ecosystem value assessment in the academic literature [21]. Since first mentioning ecosystem services in 1983, the number of articles related to these and that of their citations has been rising steeply [22]. Ecosystems provide a wide range of goods and services to mankind, which are essential for the well-being of people [23]. In order to protect ecosystems, politicians should ensure that human activities are sustainable and resources are distributed fair and efficiently [24]. Decisions of politicians and the public opinion certainly strongly influence the value and usefulness of a certain service, thus value assessment of the services is rather contradictory [25]. Some people think that it is not possible or does not make sense since economists should not give a value to incomprehensible things such as esthetics and long-term ecological benefits [26]. Thus, there can be significant differences, contradictions between economical and ecological assessments [27]. It is especially important in western countries to give a value to natural ecosystems, where great importance is attached to high productivity in economical decisions [28]. Furthermore, monetary expression of ecosystem services does not necessarily mean that these can be considered as market products or private properties [29]. For example, pollination and water regulation cannot be in private property, everybody can benefit from them; however, they cannot belong to anybody [30]. This should definitely be included in political decisions, although translation of ecosystem services assessment into suitable financial mechanisms is not completely solved yet [31]. Since it is difficult to match them with economical processes or factory goods, they have only little weight in political decisions [32]. However, economical assessment of the services and their benefits is highly important because of the control of the services [33]. Attitude toward the assessment of services is best represented by the water-diamond paradox. Water is essential for life, still little value is attached to it, diamond is not important to maintain our quality of life at all; however, it has a great monetary value [34].

While mankind is receiving beneficial services from natural ecosystems, it is changing those, thus it is extremely important to monitor changes in their status continuously since their degradation influences the quality of life of mankind as well [35]. Ecological processes are endangered by human activities, destruction and transformation of habitats and pollution result in the disappearance of natural ecosystems all over the world [36]. Despite international, national and local environmental regulations, improvement of agriculture, industry and residential areas leads to further degradation and pollution of remnant intact natural vegetation [37]. In the future, these threats will be even graver since energy and raw material demand of mankind is continuously rising [38]. Nowadays, most people live torn away from nature and often consider nature protection as a barrier of industrial development; however, ecosystem services may change the point of view, and nature protection can drive the development [39]. Assessment of ecosystem services is also a tool for decision-makers, which helps to choose from alternative management options in order to reach multiple goals [40]. It is a system that links ecology to economy, which is why economical methods should be used for assessment of components of ecological systems [41]. There are several assessment methods which help to determine the monetary value of the services, although missing data make the work more difficult [42].

2.1. Direct market valuation methods

2.1.1. Revealed preference methods

2.1.1.1. Market price method

In some cases, value of the services can be directly measured based on the market price of goods, and these goods can be directly marketed. In these cases, the value is determined by how much they are paid for during the transaction. Thus, there is no need to use complicated methods. Such goods are, for example, sawn timber, firewood, fish and other foods. The value of the goods reflects the value of the ecosystem service. The advantage of this method is that it is simple to use since it considers available price, quantity and cost information, and simple assumptions are needed. However, it has the disadvantage that several services cannot be directly marketed, and obtained information may be false and distorted; thus, the value of the service is false as well. Furthermore, it is not easy to use it in the case of large-scale changes influencing the stock and the demand on the service [43].

2.1.1.2. Production function method

This approach is used if a certain good or service is partly created by human work and partly by the contribution of an ecosystem. For example, several agricultural plants depend on pollination by insects and the value of pollination can be estimated based on the value and quality of the crops. Thus, this method has been developed to estimate indirect use values. It has the disadvantage that it is difficult to determine how tight the relationship is between ecosystem service and human contribution. Thus, this method is not often used. However, it is used to measure water quality and the change in that for example, considering lower costs of water purification, improving agricultural production data due to better pollination or improving soil quality. Thus, the quality of a marketable good has improved due to an ecosystem service. Another problem with this method can be that the researcher has to consider both human and machine contribution, which can lead to overestimation of the value of the ecosystem service. However, it has the advantage that theoretically it is rather suitable for evaluating ecosystem services since it is based on the assumption that the service and the economic advantage are strongly interconnected [44].

2.1.1.3. Cost-based methods

This method measures the value of ecosystem services so that it estimates the damage in case of loss of the service as well as it considers possible costs of substituting the ecosystem service. It is used to measure water quality and water purification costs, guard against soil erosion, storms and other natural disasters and protect natural habitats. These are not marketable goods, and the method reflects costs of creating the benefit and not the benefit itself. The method has the advantage that it supports the way the economy thinks about value and value creation. However, it has the disadvantage that in certain cases, cost of repairing the damages does not reflect the advantages obtained [45].

2.1.2. Random utility and travel cost methods

The travel cost method and the random utility method developed are based on the empiric assumption that people surely know their preferences; however, these are not always known for researchers. However, certain factors of preferences can be obtained using statistical methods. This method is mainly used to evaluate hobby fishing at lakes, rivers and seas. It measures the value of nonmarketable ecosystem services based on the money and time spent in order to get to the fishing or swimming sites. Time, money and the number of visits express the value of a site, fish and swimming [37].

2.1.3. Hedonic pricing method

This method measures the indirect value of ecosystem services, which is not marketable but can be estimated based on the observed value of a good. In order to determine the value, two goods are necessary which are the same from most points of view but differ by certain environmental conditions, for example, traffic noise or distance from a park. Difference between monetary values of the goods can be interpreted as the willingness to pay for an ecosystem service. This method is often used to estimate the benefits or costs the environmental quality has (air pollution, water pollution, noise). This means that the environmental quality can also be estimated based on the price of houses. If there are two houses which are similar almost in every respect, however, air is more polluted in the surroundings of one of them, that one may cost less. The analysis reveals if changes in the environmental conditions affect the value of a market good [46].

2.2. Stated preference methods

2.2.1. Contingent valuation

This method measures the value of ecosystem services with surveys. Filled and submitted surveys show how much people are willing to pay for certain ecosystem services. In other words, it studies how people would behave in certain situations. Since these services cannot be marketed, the questions in the surveys ask what price respondents would pay in certain situations. The survey may contain options such as a new tax, an entrance fee to a national park, annual or monthly maintenance fee or a single charge. This method is widely used to assess the value of public goods. However, respondents are often not able to determine how much they would pay for a certain service. Thus, it is rather difficult to assess what an ecosystem is worth. Several respondents highly appreciate them but cannot attach monetary value to them and the answers also depend on the income of the individuals [47].

2.2.2. Conjoint analysis

This is also a commonly used and favored method and is based on surveys. The respondent has to answer questions regarding the characteristics of a good or service. For example, he has to choose between two options which describe possible characteristics of a park (distance from the house, size, vegetation and accessibility). Statistical analysis shows the relative importance of the different features for the respondents. It reveals the distance people are willing to cover to get there. Answers can be compared with answers given regarding other recreational opportunities [48].

2.3. Biodiversity as nonmonetary evaluation approach

Individual plants or animals, which constitute the biota together, can have characteristics which directly satisfy any demand of mankind. At the same time, biota and its role in supporting the biophysical cycles in the ecosystem benefit mankind indirectly [49]. It is necessary to maintain or restore the integrity of ecosystem services so that they persist and benefit mankind in the future as well [50]. Changing biodiversity and its effect on the functioning of the ecosystem have been a rather important field of ecological research in recent decades [51]. Due to landscape transforming human activities, habitats become fragmented, isolated, and dispersion ability of species may decrease. Thus, relationship among populations and viability of species also decrease, which may lead to extension [52]. If global average temperature increases by 2–3°C by the end of the century, 20–30% of all species will be endangered by extinction [53]. Disappearance of certain species is able to change habitats physically as well, and biogeochemical cycles as well as productivity, structure and functioning of the ecosystems may also change [54]. Reduction of the number of plant species results in decreasing primary production and decomposition processes [55]. Even under stable conditions, a certain minimal number of species is necessary in order to maintain the stability of the ecosystem. Under changing conditions such as the present climate change, an even larger number of species would be necessary so that the community is able to react to changes resiliently [56].

3. Global ecological significance of ecosystem services research

Human activity is rapidly transforming the surface of the Earth, concerning biosphere, soil and water resources. This can be globally observed and changes the functioning of ecological systems. Due to this, climate changes as well because of the strong relationship between vegetation and atmosphere. Climate and vegetation mutually affect each other both locally and globally. Climate regulates the spatial distribution of vegetation types, whereas vegetation influences climate due to its physical characteristics (biogeophysical processes) and the gas exchange (biogeochemical processes) [57]. Between 1990 and 2009, 1.14 ± 0.18 Pg/year carbon was emitted to the atmosphere on average due to human activity and the disappearance of vegetation [58].

Ecological processes happen on a longtime scale, thus, damages caused by human activity will be perceptible even after decades or centuries. On a geological time scale, climatic changes were related to the changes of the Earth's orbit around the Sun, which caused large changes in the vegetation. For example, forests disappeared in Iceland due to the so-called little ice age and the Sahara, which had rich flora and fauna previously, turned to the currently known desert 6000 years ago [59]. On a shorter time scale, extreme weather events, fires, overgrazing and human activities transformed the landscape into new ecosystems, while Pleistocene megafauna became extinct [60]. In the last 300 years, human influence became extensive and intensive globally [61]. Phenomena such as deforestation, extension and intensification of agricultural areas, desertification and urbanization can be globally observed. Significant reduction of natural vegetation results in changing climate regionally and globally, deteriorating water quality, air pollution, habitat fragmentation, decreasing biodiversity, species extinction and spreading diseases [61]. In the last 2000 years, mankind reduced plant biomass by 45% through its landscape-transforming activity, the third of which disappeared during the twentieth century [62]. Human activities change soil composition, soil-forming processes, quantity and quality of water and climate [62]. After eradication of vegetation, soil is eroded, degraded, which causes irreversible changes in ecological systems and the climate [63].

Human influence on the nature is not uniform, there are still intact areas (the Amazon Basin and the Congo Basin); however, destruction will be continued in the future and the effects of these harmful processes will be perceivable in these areas with relatively intact vegetation as well [64]. Reduction of natural vegetation results in decreasing value of the connected ecosystem services, such as biodiversity, climate regulation, carbon storage capacity and water supply [65, 66]. Change in vegetation coverage is a rather significant factor, it influences ecological systems and climate and thus human life as well [67].

The fact that rapid reduction of natural vegetation might be a serious problem and would affect the quality of human life through climate change emerged some decades ago. Disappearance of vegetation and appearance of agricultural and other artificial areas have changed the albedo of areas, that is, energy exchange between the surface and the atmosphere and the climate. Due to the continuously rising human population, demand on land is also rising. This is the most decisive cause of the further degradation of natural vegetation and loss of habitats and this poses the largest threat to biodiversity. The loss is especially large in tropical regions, where biodiversity is the highest. Between 1980 and 2000, half of the new agricultural areas was created in place of cleared, previously intact forests and 28% of them in place of secondary forests [68]. Land use certainly has economic benefits and fosters the development of the countries; however, it also has a significant negative impact on the whole planet and mankind. Agriculture supplies mankind with food, thus, this activity transforms the environment to the greatest extent and contributes to greenhouse gas emission. Loss of natural vegetation and the connected ecosystem services is a problem of the same significance as food supply of mankind and economic development, maintaining and increasing the quality of life. Thus, a compromise should be agreed regarding what has to be protected and preserved and what has to be developed considering synergetic and complementary effects which may emerge.

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