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# AN ECONOMIST LOOKS AT ECOSYSTEM SERVICES

## 1. Introduction

The last five decades witnessed enormous progress in developing valuation techniques applied to non-market goods (i.e. the goods that do not have market prices). These can be broadly divided into direct and indirect techniques. The former aim at capturing them directly e.g. by asking people "how much they are willing to pay". The latter derive values from observing prices not for the good of interest, but rather for a complementary good whose characteristics shed some light on people's relevant preferences.

These techniques were successfully tested in many regions of the world, including Poland. The best known exercise of this sort is the one published by *Nature* in 1997, where an attempt was made to estimate the global economic value of annual ecosystem services. Numerous subsequent studies have allowed for much more accurate assessments. Consequently, researchers addressing valuation problems have an extensive accumulated research experience to rely on.

This chapter lists ecosystem services and discusses what techniques can be applied in order to assess their economic value.

## 2. Types of economic values

In earlier papers readers were offered more extensive discussions of how economists understand values.[1] Here I focus on concepts that are immediately relevant for valuating ecosystem services.

[1] T. Żylicz, (1997), *Economic Valuescand Polocy Implications*, [in:] A. Nordgren (ed.), *Science, Ethics, Sustainability: The Resposibility of Science in Attaining Sustainable development*,

For several generations, people looked for material sources of economic values such as e.g. human labour, land, or energy. At the turn of the 19th and 20th century, a totally different approach was developed. Economic values reflect not how they originate but rather how they satisfy human needs.

In modern economics, the *Total Economic Value* (TEV) consists of several elements, some of which may relate to less tangible non-material characteristics that are nevertheless measurable.[2] In broad terms, TEV consists of *Use Value* (UV) and *Non-Use Value* (NUV), the latter being sometimes referred to as "Passive Use Value". *Use Values* are divided into *Direct Use Values* (DUV) and *Indirect Use Values* (IUV). An example of DUV is the value derived from swimming in a lake, while an example of IUV is provided by stabilizing a local water table as a result of protecting the lake. Often DUV is linked to the physical consumption of a good, but – like swimming in a lake – it is not a prerequisite. John Krutilla observed that what people are willing to pay for a good or a service may not be exhausted by UV in any sense.[3] Thus he introduced the concept of NUV as a measure of the residual. The NUV is often divided into *Existence Value* (EV) and *Bequest Value* (BV). The former is linked to what people may attach to the mere existence of a good, while the latter represents the value of handing over the good to next generations. All the concepts referred to here are relevant for any values, not only the ones linked to ecosystem services.

The formula TEV = UV+NUV = DUV+IUV+EV+BV which relates values – i.e. ratios applied when sacrificing one good for another – is not universally accepted. Even though the labour theory of value (popular in the 19th century) does not belong to modern economics, there are a number of similar approaches that are used in applications until now. Two of them are particularly popular. These are the energy and land theories of value. The former is based on the assumption that exchange ratios tend to reflect the amount of energy used – directly and indirectly – to produce a good. The latter posits that the ratios should depend on the amount of land used – directly and indirectly – to produce a good. Values calculated according to the former are denominated in calories or joules, while the values calculated according to the latter are denominated in hectares. Actual choices involve monetary valuations which means that everything should be converted into money. Nevertheless some analysts claim that there are goods which do not allow for monetary valuations.

Uppsala University, p. 105–114; T. Żylicz, (2012), *Valuating ecosystem services*, „Ekonomia i Środowisko", 2(42), p. 18–38.

[2] D. Dzięgielewska (Lead Author), T. Tietenberg and S. Niggol Seo (Topic Editors), (2007), *Total economic value*, [in:] *Encyclopedia of Earth*, Ed. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment), http://www.eoearth.org/article/Total_economic_value

[3] J. V. Krutilla, (1967), *Conservation Reconsidered*, "The American Economic Review", Vol. 57, Issue 4, p. 777–786.

Statistical life is an example of a good that is thought of by many as impossible to put a price tag on. This, however, depends on how the good is defined. First of all, statistical life has nothing to do the actual life of a concrete person; for many people this is simply sacred and priceless, and economists do not pretend that they can contribute to a debate on human life. Even though sometimes the life can be exchanged for money (for instance, a murderer kills somebody for a small amount of money, or somebody else rescues a relative from death by paying a large bounty), economists explain that these are not routine transactions reflecting people's preferences. Instead, economists analyze how people choose when they have an opportunity to change (either increase or decrease) a small probability of death. Based on such choices, it is possible to infer their preferences with respect to saving lives in large populations, reflected in the so-called *Value of Statistical Life* (VSL), which is a finite number. It is then an easy exercise to calculate the so-called *Value of Life Year* (VOLY) gained or lost, for example, as a result of a policy or a programme.

Nevertheless some analysts insist that even a statistical life cannot be priced. But they admit that a person whose life is saved may not be in perfect health. This led to the concept of *Quality Adjusted Life Years* (QALY) which captures the fact that a life year gained may be perceived as less valuable if the person affected enjoys imperfect health. Advocates of the QALY concept argue that everything that affects humans – be it air pollution, noise, landscape, recreation opportunities *etc.* – ultimately translates into QALY.

A similar approach can be taken with respect to non-human life. The equivalent of a "person-year" is a "hectare-year". Additionally, if a hectare enjoys natural biological diversity, it is calculated as a full hectare. If, on the contrary, the field is affected by impaired diversity, it is calculated as a fraction of the actual area. This led to the concept of *Biodiversity Adjusted Hectare Years* (BAHY). Its advocates argue that everything that affects non-humans – be it air pollution, noise, climate *etc.* – ultimately translates into BAHY.[4]

Nevertheless, if there is a trade-off between QALY and BAHY, and obviously some programmes are oriented towards human well-being rather than nature, then the question remains how to translate QALYs into BAHYs and *vice versa*. Therefore money equivalents of everything are called for, despite efforts to free environmental improvements from economic values. It is improper to simply multiply physical units – e.g. QALY or BAHY – by fixed "prices" attached to these units. Analysts should always strive to understand the trade-offs people actually make when they take decisions.

The approach making a strict difference between humans and nature (not to be valued in money terms), and non-living resources (that can be valued in money

[4] B. P. Weidema, (2008), *Using the budget constraint to monetarise impact assessment results*, "Ecological Economics", Vol. 68, p. 1591–1598.

terms without much hesitation) is also questionable on theoretical grounds. Changes that affect non-living resources – leading e.g. to cheaper computers – may ultimately save people's lives and hence contribute to QALYs. Attempts to free value assessments from money considerations can never be successful. Economics is about how people make choices which – by their very nature – are complex and multifaceted.

Economic values are thus very diverse and they call for appropriate measurement techniques. In their attempts to capture values implied by people's choices, economists must understand what specific needs are served by what they analyse.

## 3. Valuation techniques

Economic values exist whenever people make choices, irrespective of whether they buy and sell in competitive markets. Therefore economic values existed in feudal and in centrally-planned economies. In a market economy they are simply more visible and easier to capture (by looking at market prices), but even there they are not always effortlessly available to a researcher.

Economists distinguish between private and public goods. The former can be easily bought and sold in markets. The latter complies with two principles: non-exclusion and non-rivalry. The first means that if a good is provided, it is impossible to exclude anybody from using it. The second means that if a unit of a good is used by somebody, the same unit can be used by somebody else without adversely affecting the original user. A lighthouse and an air defence system are textbook examples of public goods, but there are more interesting examples studied in environmental management.

Environmental quality is an example of a public good. If it is low then everybody is adversely affected, and the gravity of individual damage does not depend on the number of victims. If – on the contrary – one makes an investment to improve it, then everybody will benefit and the level of individual gains will not depend on the number beneficiaries. Also biodiversity possesses characteristics of a public good. Its benefits can be enjoyed by everybody and – at least within certain limits – an additional user does not affect previous ones adversely.

Private goods can be exchanged in markets and their values can be derived from their prices. Public goods are a different story. Market behaviour is distorted as a result of the non-exclusion principle. People understand that if a public good is provided, then nobody can be excluded from using it. Therefore some take advantage of this fact by being 'free-riders', i.e. they use the good while pretending that they do not care for it and consequently they do not finance its provision. Economists demonstrate that the market supply of a public good is lower than justified by social preferences. An alternative is to supply it through a political process (outside the market), but this requires that public authorities are able to measure how much of the good is demanded by the society. Putting it in the language of economics, they should know how much people are willing to pay jointly in order to have the good provided.

Until the 1940s there were no methods to evaluate public goods. For instance, people felt that a unique landscape might have a value, but thought that this was beyond economics. Harold Hotelling was the first economist to suggest that the value of a scenic site visited by tourists (a public good) can be derived from the cost they incur in order to get to the place (travel is a private good).[5] Robert Davis was the first one to demonstrate that if the good is not private (and hence it does not have a market price), its value could be determined by simply asking people how much they are willing to pay in order to use it.[6] These two ideas started a whole new domain of economics devoted to the valuation of non-market goods.

Economic values can be best reflected in competitive market prices. If the market is a non-competitive one, then prices are distorted by strategic behaviour of its agents, and consequently they do not necessarily inform well about people's preferences. However, if there is no market – as in the case of public goods – there are no market prices to rely on at all. Typical environmental goods and services belong in this category.

There are two valuation techniques developed for non-market goods: indirect and direct ones. The former derive economic values from so-called surrogate markets where people buy and sell goods that are complementary to the one in question. The latter refer to a hypothetical market where the good in question could be bought and sold; economists ask people directly how much they would be willing to pay (WTP) for what they do not have, or how much they would be willing to accept (WTA) for being dispossessed of what they have. Of course, both types of questions are hypothetical and there is no guarantee that answers will truthfully reveal people's preferences. Nevertheless there were great efforts undertaken (especially over the last two decades) to make the direct methods credible.

Indirect valuation techniques are considered by economists more reliable, since they are based on actually revealed preferences. The prime example of this approach is the Travel Cost Method (TCM) first suggested by Harold Hotelling. The idea is very simple. The more people visit the place, the more valuable it is. Also when they travel longer distances or pay higher costs, the goal of their journey must be more valuable. The idea is quite simple, yet its implementation is not. The same records of visitations can be interpreted in several ways. Even the cost incurred by an individual visitor is problematic. For instance, there are no

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[5] H. Hotelling, (1949), *An Economic Study of the Monetary Valuation of Recreation in the National Parks*, Washington, DC: U.S. Department of the Interior, National Park Service and Recreational Planning Division.

[6] R. K. Davis, (1963), *The Value of Outdoor Recreation: An Economic Study of the Maine Woods*, Ph.D. dissertation, Harvard University.

definitive solutions on how to account for travel time. Many economists argue that the time spent in travel has its value reflected by earnings lost. But as it is difficult to practically assess these earnings, some researchers simply do not include them in the travel cost. Another unsolved issue is how to allocate the cost of multipurpose trips. Some analysts exclude such trips while others try to allocate the cost according to the weight attached to any of the purposes as declared by visitors themselves. Of course, either way is questionable.

If the costs of individual travel are somehow determined, it remains far from obvious what conclusions can be drawn from these observations. Economic theory implies that the value people attach to the visit should not lower than the travel cost. But for some visitors it can be higher. Moreover, the analysis typically captures only a fraction of those who are actually visiting a place. There are very sophisticated econometric techniques to reveal demand functions based on the observed distribution of travel costs. Unfortunately the results are sensitive to assumptions regarding theoretical distributions those observed are sampled from.

Despite theoretical problems, TCM proved to be a powerful instrument for environmental protection. Valuable places are sometimes subject to a pressure to destroy them in order to provide some economic benefits. For instance, a canyon can be destroyed by constructing a water retention reservoir to produce hydroelectricity. The benefit from destruction is the net value (i.e. after subtracting production costs) of "clean" electricity. The alternative use of the canyon is tourist recreation. If the TCM demonstrates that this alternative is more valuable than the electricity, then the dam does not make economic sense. Similarly, a wetland can be destroyed by draining it in order to enhance agricultural production. If the TCM demonstrates that the wetland provides sufficiently high tourist recreation benefits then its drainage loses its economic justification.

Another example of the indirect approach is provided by the so-called Hedonic Price Method (HPM). Let us look at the case of silence. This is a typical non-market public good. It can be neither bought nor sold. However, there is a complementary private good, namely real estate. If there are two identical houses, one of which is located in a silent place while the other one is in a noisy neighbourhood, it can be expected that the former will get a higher price. If everything else is the same, then the price difference can be attributed to the silence. In other words, the difference indicates how much people are willing to pay for silence. Of course, it would be unrealistic to find two almost identical estates so that the price difference can be attributed to a single cause. In practical applications, researchers analyze a large number of transactions and look for correlations of prices with many attributes that may possibly affect the price. Based on econometric modelling, they can determine to what extent a specific phenomenon – like, for instance, silence – changes the price. The number found can then be interpreted as the value of an attribute that *per se* is not a market good.

There are also other techniques aimed at analyzing people's revealed preferences in order to estimate values of non-market goods. Another one that can also be used to estimate, e.g., the value of silence is the Avertive Behaviour Method (ABM). Again the intuitive justification is quite straightforward. People are willing to pay more for noise-proof windows than what they pay for 'normal' ones. Therefore the difference can be attributed to how much they value silence. Like before, this practical inference is based not on a single comparison, but rather on a large data set where prices of windows are correlated with many attributes, one of which is a window's ability to reduce the noise.

Another fairly obvious method to estimate the value of a natural phenomenon is Productivity Loss (PL). Insects pollinate flowers and let the plants bear fruits. This has been known by orchard owners who appreciate the presence of bees in their neighbourhood. If there are no insects, the crops will be lower. This loss of productivity tells us about the value of the service provided by nature. Alternatively, to the extent that flowers can be pollinated manually, one can contemplate establishing an artificial mechanism to substitute for the lacking ecosystem service. This is called a Replacement Cost (RC) method, and can be applied to calculate how much it would cost to replicate a function lost. All these approaches can also be interpreted as approximating shadow prices in a welfare maximization problem, where one of the control variables is an environmental good.

If a surrogate market cannot be easily identified, the value of a non-market good has to be assessed directly, by asking people about their WTP or WTA in a hypothetical market. The earliest technique developed for this purpose is the so-called Contingent Valuation Method (CVM). It owes its name to the fact that a respondent is presented with a hypothetical scenario of the provision of the good in question, and his or her answers are made contingent upon acceptance of this scenario. There are two basic formats of CVM. The WTP/WTA question can be open-ended, OE (e.g. *How much are you willing to pay for …? / How much would you be willing to accept if deprived of …?*), and respondents are expected to quote a number. Alternatively, respondents can be presented with a number and asked if they were WTP/WTA for the scenario shown. They are supposed to answer *yes* or *no*. This format is called dichotomous choice (DC), since the choice respondents have – like in a referendum – is a dichotomous one.

The successful development of CVM has not stopped the search for alternative methods of soliciting people's preferences for non-market goods. A technique which is now becoming more and more popular is called the Choice Experiment (CE). It differs from CVM in that it is not confined to a single WTP/WTA question. Like in CVM, respondents are presented with the scenario of a possible provision of the public good to be evaluated. The good is characterized by several attributes and each of the attributes can be measured at several levels. The advantage of CE is that each respondent provides many statistical observations instead of a single one, as in the classical CVM. Consequently, CE surveys lead to better statistical estimates at a fraction of the cost required by CVM ones.

## 4. Valuation results

The second half of the 20th century, and especially its last decade, witnessed an eruption of valuation results relevant for environmental protection and management. Perhaps the best known example is the exercise compiled by Robert Costanza and published in *Nature* (reprinted in *Ecological Economics* a year later).[7] The team of Costanza identified 18 typical ecosystems, such as e.g. boreal forest, grassland, wetland, and so on, and 17 key 'services,' such as climate regulation, pollination, recreation, and so on. Each ecosystem may potentially provide all these services, although some of them to a very limited extent. The 18x17 matrix has 306 entries, each of which gives the value of a specific service provided by one hectare of the specific ecosystem. Costanza and his collaborators reviewed all valuation results available to them and tried to fill the matrix with numbers. Most of the entries were empty either because a given service was not provided by a given ecosystem at a measurable level, or because they could not find an appropriate estimate in the literature of the subject. Nevertheless the numbers aggregated for given ecosystems multiplied by their areas gave a total estimated value of the world's ecosystem services.

The value arrived at the end of this exercise turned out to be 33 trillion USD (1994), i.e. more than the global GDP, which was used by some critics as an argument to ridicule the result. This criticism is not justified though. The GDP gives the value of all goods and services that are exchanged in the market. There is absolutely no reason to think that ecosystem services are a part of market transactions and consequently their value should be related to GDP.

Nevertheless there are other reasons to question the correctness of this valuation. First, the studies used by the team could be simply inaccurate. Second, it is likely that the values calculated were not always comparable. The authors admitted that some of them were gross and some were net, even though all of them should have been net ones (the difference between gross and net values is the cost of provision, which should be subtracted if the result is to be comparable with GDP). Third, the numbers were coarse aggregates not necessarily reflecting services provided by specific sites. Finally, most of the entries in the matrix were based on single studies, and it is unlikely that these studies were fully representative for all ecosystems and all services they stood for.

Despite these limitations, the survey of Costanza *et al.* serves as a useful reference. It would be inappropriate to pick rates from the matrix and multiply them by the number of hectares in order to establish the value of a given site. However, for instance, it is fair to argue that – irrespective of what may possibly come out of specific site surveys – the per hectare value of ecosystem services provided

[7] R. Costanza *et al.*, (1997), *The value of the world's ecosystem services and natural capital*, "Nature", May 15, Vol. 387, p. 253–260.

by a wetland is likely to be an order of magnitude higher than the respective value of a forest (the matrix implies the ratio of 49). Looking at the matrix gives a rough approximation of what can be expected from a site-specific survey.

In a recent update of the study, Costanza *et al.* tried to arrive at more accurate estimates.[8] It turned out that – based on a much larger set of measurements – the value of the world's ecosystem services is considerably higher. The original number would have been 46 trillion 2007 dollars. The new number is 145 trillion (assuming that the area of ecosystems evaluated has not changed since 1997), or 125 trillion (when land use changes between 1997 and 2011 are accounted for). Thus the more recent estimations tend to evaluate ecosystem services more than three times higher than earlier. In marine ecosystems the most dramatic increase was recorded for coral reefs (from 8,384 to 352,257 in 2007 USD/ha/yr). In terrestrial ecosystems it was tidal marsh and mangroves (from 13,786 to 193,843 in 2007 USD/ha/yr).

All the techniques mentioned in Section 2 were tested in Poland. Their review covering the period of 1994–1999 is included in *Costing Nature in a Transition Economy. Case Studies in Poland* written by T. Żylicz.[9] In particular, the book explains how CVM surveys were prepared and carried out. WTP for reduced eutrophication of Baltic Sea was the focus of a number of these. Both DC and OE questions, and two main types of interviews – face-to-face and mail – were tested. It should also be noted that for the first time the same survey scenario was implemented in three countries. The same study was simultaneously executed in Lithuania, Poland and Sweden. The results were then used to analyze prospects for establishing a Baltic-wide cooperation programme aimed at cleaning-up the sea.[10] Apart from the Baltic studies, there were CVM surveys of WTP for improved protection of the Biebrza wetland. Indirect valuation techniques were represented in the book by the TCM, applied in order to estimate the value of clean water that many people in Warsaw pumped from public Oligocene wells (the tap water was of a much lower quality, but it did not require travelling).

After 1999, CVM was used in a couple of new applications. Most notably it was used to study people's WTP for time savings,[11] reduced health risks from air pollution,[12] improved quality of surface water,[13] for improved medical

[8] R. Costanza *et al.*, (2014), *Changes in the global value of ecosystem services*, "Global Environmental Change", Vol. 26, p. 152–158.

[9] T. Żylicz, (2000), *Costing Nature in a Transition Economy. Case Studies in Poland*, Edward Elgar, Chelthenham.

[10] A. Markowska, T. Żylicz, (1999), *Costing an international public good: The case of the Baltic Sea*, "Ecological Economics", Vol. 30, p. 301–316.

[11] A. Bartczak, (2002), *Wartość czasu podróży* [*The value of travel time*], „Ekonomia", nr 7, p. 100.

[12] D. A. Dzięgielewska, (2003), *Essays on Contingent Valuation and Air Improvement in Poland*, Ph.D. dissertation, Yale University, New Haven.

[13] A. Markowska, (2004), *Koszty i korzyści wdrożenia w Polsce Dyrektywy 91/271/EWG W Sprawie Oczyszczania Ściekow Komunalnych* [*Costs and benefits of implementing in Poland*

care,[14] as well as for reduced accident risk.[15] An international study aimed at lake recreation was carried out in Poland, the Czech Republic and Norway.[16]

An HPM study of housing prices in Warsaw revealed interesting characteristics of the real estate market in Poland.[17] Another HPM was carried out in order to check if real estate prices were positively affected by a water retention reservoir on the lower Vistula river (they were not).[18] A variant of HPM – a so-called hedonic wage method (where wage differentials are linked to working conditions) – was performed in order to estimate people's WTP for reduced accident risk.[19] Yielding more consistent results, the study turned out to be much more credible than a simultaneous CVM survey. This confirms economists' conviction that whenever possible indirect methods based on revealed preferences are preferred to direct methods based on stated preferences.

The recreation value of Polish forests was estimated several times using the TCM and other methods. Two of these studies were focused on the Bialowieza Primeval Forest.[20] One covered ten different sites representative for Polish public forests.[21] Contrary to earlier hypotheses,[22] they revealed that people's WTP for forest recreation is higher than in Western Europe, and – moreover – it is remarkably higher for the Bialowieza Primeval Forest.

More recent studies applied the CE technique. As an alternative to CVM, it was used in Markiewicz's and Giergiczny's studies on the VOSL. It was used

*the Council Directive 91/271/EEC concerning urban waste-water treatment*], praca doktorska, Uniwersytet Warszawski [Ph.D. dissertation, University of Warsaw].

[14] O. Markiewicz, (2008), *Analiza opłacalności programów ochrony zdrowia na podstawie wyceny statystycznego życia i wyceny dodatkowego roku przeżycia w Polsce* [*Efficiency of health protection programmes in Poland based on the Value of a Statistical Life, and the Value of a Life Year*], praca doktorska, Uniwersytet Warszawski [Ph.D. dissertation, University of Warsaw].

[15] M. Giergiczny, (2008), *Value of a Statistical Life – the Case of Poland*, "Environmental and Resource Economics", Vol. 41, Issue 2, p. 209–221.

[16] M. Czajkowski, A. Markowska, O. Markiewicz, A. Bartczak, M. Scasny, J. Melichar, H. Skopkova, (2007), *Lake Water Quality Valuation-Benefit Transfer Approach vs. Empirical Evidence*, „Ekonomia", nr 19, p. 156–193.

[17] M. Borkowska, M. Rozwadowska, J. Śleszyński, T. Żylicz, (2001), *Environmental Amenities on the Housing Market in Warsaw. Hedonic Price Method Research*, „Ekonomia", nr 3/2001, p. 70–82.

[18] A. Jacewicz, J. Żelaziński, T. Żylicz, (2002), *Prawdy i mity o stopniu i zbiorniku wodnym we Włocławku* [*Truths and myths about the Wloclawek dam*], „Gospodarka Wodna", nr 8/2002, p. 326–329.

[19] M. Giergiczny, (2008), *op. cit*.

[20] M. Buszko-Briggs, M. Giergiczny, J. Ziezio, T. Żylicz, (2004), *Wartość ekonomiczna Puszczy Białowieskiej* [*Economic value of the Bialowieza primeval forest*], WWF–Polska, Warszawa; M. Czajkowski, M. Buszko-Briggs, N. Hanley, (2009), *Valuing Changes in Forest Biodiversity*, "Ecological Economics", Vol. 68, p. 2910–2917.

[21] A. Bartczak *et al.*, (2008), *op. cit*.

[22] UNECE/FAO, (2005), *European Forest Sector Outlook Study. 1960–2000–2020*. Main report, Geneva.

as well by Czajkowski *et al.* in order to decompose people's WTP for improved protection of the Bialowieza Primeval Forest into parts reflecting environmental quality, and the protection regime. Czajkowski (2008) aimed at estimating people's WTP for enhanced biodiversity protection in the Bialowieza Primeval Forest.[23] Biodiversity was characterized by, *inter alia,* three attributes: (1) natural ecological processes, (2) rare species, and (3) ecosystem components. Each of the attributes was contemplated at three possible levels: (a) *status quo*, i.e. no improvement, (b) partial improvement, and (c) significant improvement. All types of improvements were carefully explained and quantified. The fourth attribute that was presented to respondents was a financial contribution, defined as a tax to be paid for 10 years (also in several variants, including no tax at all – linked to the *status quo* variants). Every respondent was given several options to choose from. Their choices were then analysed in order to determine what the (implicit) WTP was for a specific change in biodiversity. Yet another study written by Żylicz and Giergiczny applied CE in order to identify forest characteristics that provide visitors with the highest recreation values.[24] An earlier version of the study was published by Czajkowski *et al.*[25]

## 5. Types of ecosystem services

People understand that ecosystems provide invaluable services, and attempts to create a synthetic environment for them to live in are ill-conceived. Nevertheless – given the concept of an economic value, which reflects people's willingness to sacrifice something for something else – the economic values of these services are finite by definition. People who make specific choices may be not fully aware of their consequences. Neither are they always well educated. Yet economics is about how people behave, even if this behaviour can be considered disappointing.

The economic and social role of living resources is multifaceted. It would be redundant to elaborate on how important these resources are. In order to focus attention, they can be classified into one or several dozen of categories. For instance, the famous Costanza *et al.* (1997) review identified seventeen categories to be assessed.[26] These were:

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[23] M. Czajkowski, (2008), *Nośniki wartości dóbr środowiskowych* [*Value Drivers of Environmental Goods*], praca doktorska, Uniwersytet Warszawski [Ph.D. dissertation, University of Warsaw].

[24] T. Żylicz, M. Giergiczny, (2013), *Wycena pozaprodukcyjnych funkcji lasu. Raport końcowy* [*Assessment of non-timber benefits in forestry. Final report*], Uniwersytet Warszawski.

[25] M. Czajkowski, A. Bartczak, M. Giergiczny, S. Navrud, (2013), *Providing Preference-Based Support for Forest Ecosystem Service Management in Poland*, "Forest Policy and Economics", p. 1–12 [http://dx.doi.org/10.1016/j.forpol.2013.11.002].

[26] R. Costanza *et al.*, (1997), *op. cit.*

1. Gas regulation,
2. Climate regulation,
3. Disturbance regulation,
4. Water regulation,
5. Water supply,
6. Erosion control,
7. Soil formation,
8. Nutrient cycling,
9. Waste treatment,
10. Pollination,
11. Biological control,
12. Habitat / refugia,
13. Food production,
14. Raw materials,
15. Genetic resources,
16. Recreation,
17. Cultural.

Some of them could be analysed jointly, and some can be further disaggregated. In order to maintain comparability with the work carried out elsewhere, we will use the same classification. Some of the items are self-evident, but some may need interpretation for non-ecologists.

Climate regulation (2) is commonly linked to carbon dioxide sequestration, and hence it could be included in (1). However the two categories do not overlap since (2) includes benefits – such as e.g. albedo control – that are not linked to the chemical composition of the atmosphere. Likewise disturbances (3) are much broader than simply climate change; they include what ecologists call "resilience", i.e. ability to cope with changing circumstances. Also water regulation (4) is not simply a specific aspect of (2). Water supply (5) is understood as provision of water for all economic activities including human consumption. Erosion control (6) and soil formation (7) address the availability of what constitutes a key input into agricultural production. But erosion control is not only about losing this input, but also about spoiling the landscape by letting an upper layer of the earth disappear. Nutrient cycling (8) and waste treatment (9) address similar problems. They are about how to provide living resources with what they need. The nutrients are not easily available, either because they are located far from where they are needed, or because they are trapped as "human waste" and have to be decomposed into what is useful for other forms of nature; ecosystems may provide "services" that otherwise require an extra effort. Pollination (10) and biological control (11) play similar roles. Pollination can be made artificially; likewise pest control can be accomplished chemically or mechanically. Habitat / refugia (12) and genetic resources (15) contribute to biodiversity conservation. Food production (13) and raw materials (14) do not require explanation. The last two categories – recreation (16) and cultural (17) – refer to specific needs of human population. Even though they are sometimes considered non-essential for welfare, they are indispensable and they have attracted economists' attention for decades.

> A world from which solitude is extirpated, is a very poor ideal. Solitude, in the sense of being often alone, is essential to any depth of meditation or of character; and solitude in the presence of natural beauty and grandeur, is the cradle of thoughts and aspirations which are not only good for the individual, but which society could ill do without. Nor is there much satisfaction in contemplating the world with nothing left to the spontaneous activity of nature; with every rood of land brought into cultivation, which is capable of growing food for human beings; every flowery waste or natural pasture ploughed up, all quadrupeds or birds which are not domesticated for man's use exterminated as his rivals for food, every hedgerow or superfluous tree rooted out, and scarcely a place left where a wild shrub or flower could grow without being eradicated as a weed in the name of improved agriculture.[27]

These words were written by John Stuart Mill in the first half of the 19th century, long before environmental protection became fashionable in the 1970s. The recreational and cultural benefits provided by natural ecosystems are real and measurable. Many of the techniques reviewed in Sections 2–3 above have been developed in order to assess the value of such benefits. Other ecosystem services require a different approach. Food production and raw materials are fairly easy to evaluate since – as market goods – they have market prices which inform about their economic value. The same applies (although with caution) to water supply.

Yet other ecosystem services may require different measurement techniques. Soil formation, pollination, biological control, and disturbance regulation are well suited for PL and RC methods, since a natural function lost implies obvious productivity losses that – at the same time – can be avoided by replacing the missing service by some sort of economic action. Erosion is a more difficult case, because what matters is not just the soil loss, but landslides and landscape changes which may imply other types of damage as well. Nutrient cycling and waste treatment can be assessed using the PL and RC methods.

International public goods are a different story. Formally, their values can be estimated as shadow prices, like for other "local" ecosystem services. The problem, however, is that their availability can be determined at the planetary level only. Carbon sequestration carried out by a forested area may contribute to climate protection, but the effect depends not on what was done in the area, but rather what was done (or not done) everywhere else. Hence calculating relevant shadow prices makes sense at the planetary level only. This applies not only to climate regulation – which is the best known international public good – but also to other goods of this sort, such as biodiversity. Consequently, ecosystem services providing

[27] J. S. Mill, (1848), *Principles of Political Economy*, Book IV, Chapter VI, John W. Parker, London.

gas regulation and climate regulation cannot be estimated for a given area or a given project. They can be estimated only in a global welfare context.

For instance, by applying such an approach it was estimated in the 1990s that the welfare loss avoided by removing one tonne of carbon dioxide from the atmosphere would be roughly USD 10 if the global emission is reduced from hypothetical 60 billion tonnes per annum to 30 billion tonnes (Fankhauser *et al.* 1997). Later studies demonstrated how the crucial role of global welfare functions and their mathematical properties (Roughgarden and Schneider 1999). It is estimated that the benefit of removing one tonne of carbon dioxide in the future is even higher, perhaps over USD 100 in the 22$^{nd}$ century. Assuming a certain capacity of carbon retention by an ecosystem, such estimates allow for attaching certain values of the ecosystem services. In particular, assuming that a boreal forest grows at the pace of 4 $m^3$ of timber per hectare per annum, and making additional assumptions regarding carbon sequestration by trees, it can be estimated that every hectare of forest absorbs 10 tonnes of carbon dioxide per year. Multiplying this amount by the shadow price of carbon dioxide gives the value of this specific forest's ecosystem service. The procedure is very cumbersome, complicated and uncertain, but there are no simpler ways of determining such values in the case of global public goods like gas regulation and climate regulation.

In the case of biodiversity, the problem is even less thoroughly researched. It is evident that the human economy derives benefits from maintaining wildlife in all its forms, but no studies allow for attaching reliable values. Whatever value is attached to services such as habitat / refugia or genetic resources is very uncertain and based on incidental and local benefits rather than actual (global) ones. The same applies to water regulation. This is also a global public good, although much less thoroughly researched by economists than the climate. At the same time, to some extent it can be appropriated at scales lower than the planetary one. Thus whatever is computed as an ecosystem service allowing for water regulation is likely to be an approximate local benefit (even though this does not fully reflect its role).

De Groot *et al.* provide a slightly different typology of ecosystem services.[28] They introduce four broad categories, such as Regulation functions (comprising 1–11 from Costanza *et al.*), Habitats functions (12, and non-agricultural food production), Production functions (agricultural food production, 14–15, and medicinal and ornamental resources), and Information functions (16–17, as well as aesthetic information, spiritual and historic information, and science and education). Thus their list is somewhat longer and consists of twenty-three items.

[28] R. S. De Groot, M. A. Wilson, R. M. J. Boumans, (2002), *A typology for the classification, description and valuation of ecosystem functions, goods and services*, "Ecological Economics", Vol. 41, p. 393–408.

The lists of ecosystems services discussed above are not universally accepted. For instance a UK national study covered twenty-one services.[29] These were:

> Marine food production, Woodland related food production, Pollination services, Maintaining genetic diversity, Bioprospecting, Biodiversity: Non-use values, Timber production, Carbon sequestration, Carbon storage, Water quality, Water quantity, Flood protection: Inland, Flood protection: Coastal, Pollution remediation, Energy (renewable and non-renewable) and Raw Materials (fish meal, seaweed, aggregates), Employment, Game hunting, Amenity value of warmer climate, The amenity value of nature, Education and environmental knowledge.

Alternatively one can refer to a short list of four types recommended by the European Union.[30] They were developed within TEEB (*The Economics of Ecosystems and Biodiversity*), a project launched by the United Nations Environment Programme. They are:

1. Provisioning services (products obtained from ecosystems such as food, fresh water, wood, fiber, genetic resources and medicines);
2. Regulating services (benefits obtained from the regulation of ecosystem processes such as climate regulation, natural hazard regulation, water purification and waste management, pollination or pest control);
3. Habitat services (habitat for migratory species and maintaining the viability of gene-pools);
4. Cultural services (non-material benefits that people obtain from ecosystems such as spiritual enrichment, intellectual development, recreation and aesthetic values).

A more practical approach has been developed by the European Commission in its CICES (*Common International Classification of Ecosystem Services*) (CICES 2014) framework.[31] Referring to previous classifications, it also makes a distinction between "Provisioning", "Regulation & Maintenance", and "Cultural". But it also recommends to look at nutrition, materials, and energy separately. Moreover, nutrition, for instance, is further subdivided into biomass and water (with an additional distinction between freshwater and groundwater). Energy is further subdivided into "Plant-based resources", and "Animal-based resources", and so on. Consequently, the number of items is over forty. This very detailed classification may prove to be of some practical significance, yet it does not seem to capture anything more than the 'classic' list of Costanza *et al.* (1997) (and Costanza *et al.* (2014)).

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[29] R. Brouwer, L. Brander, O. Kuik, E. Papyrakis, I. Bateman, (2013), *A synthesis of approaches to assess and value ecosystem services in the EU in the context of TEEB. Final Report*, Free University of Amsterdam.

[30] High-Level Conference on Mapping and assessment of ecosystem and their services (MAES) in Europe 2014, http://biodiversity.europa.eu/topics/ecosystem-services

[31] CICES (Common International Classification of Ecosystem Services) (2014), CICES V4.3, European Environment Agency, Copenhagen, http://cices.eu.

The concept of ecosystem services is still somewhat vague. People agree that nature is wonderful, and provides economies with valuable inputs. Nevertheless, attempts to quantify its value have proven difficult. It is a great challenge to make sure that valuation techniques are free from double-counting and lead to assessments that can be compared with one another. Unless scientists solve these problems, there is no chance to have ecosystem services adequately included in economic analyses.

## 6. Conclusions

Recent decades have been marked by an increased interest in ecosystem valuation studies. This phenomenon is probably the result of two factors. First, our understanding of how ecosystems affect economies and societies has improved as a result of extensive field research. Second, there has been tremendous progress in economic valuation techniques, making it possible to credibly estimate values of goods and services that are not exchanged in markets.

Ecosystem services are important and indispensable. Their value depends not only on their attractiveness for tourists, but also on their role in natural processes. As it turns out, the latter can also be of interest to people. Their role in natural processes is captured in so-called non-use values. They can be best estimated by Choice Experiments and other stated preferences rather than revealed preference methods. This poses quite a challenge before the academic community, whose exposure to this trait of valuation research has been limited to date.

The concept of economic value has been widely misunderstood. Natural scientists expect economists to compute 'true' values of what ecosystems provide economies. Some economists even dream about discovering the "actual" role of nature, not as it is perceived by people, who may not be very aware of their dependence on nature. As stated by, e.g.. Costanza *et al.*:[32]

> There are multiple ways to assess [the contribution of ecosystems to human welfare], some of which are based on individual's perceptions of the benefits they derive. But the support of sustainable human well-being is a much larger goal […] and individual's perceptions are limited and often biased […]. Therefore, we also need to include methods to assess benefits to individuals that are not well perceived, benefits to whole communities, and benefits to sustainability […].

While it is true that people's preferences can be strange, nevertheless economists have to analyse them as they are. It should be noted that this does not mean people's preferences are fixed for ever. By all means, they are not. However, it is the role of educators, journalists, writers, artists, preachers, and others to inspire

[32] R. Costanza *et al.*, (2014), *op. cit.*

people to change their preferences. If economists join these efforts, they can do so in their private capacity. In particular, it would be against economics to look for "values" that people do not understand or appreciate, such as e.g. sustainability benefits. In contrast, benefits which accrue to communities are captured by economists when they study public goods. Once again, economic values reflect the preferences of lay people, some of whom are stupid or ill-informed. There are no economic values to specifically reflect the preferences of people who are clever and virtuous. Of course there are values that such people live by, but they have nothing in common – except for linguistic proximity – with economic values.

Valuation exercises raise another important question. Some analysts suggest that ecosystems need to be evaluated not in terms of their actual, but rather their potential contribution to human welfare. In other words, if a piece of fertile land is used for purposes that could have been served by something less fertile, then its potential (not actual) output should be accounted for. This does not seem to be an appropriate approach. If the valuation of ecosystem services was to correspond to values attached to standard economic activities, they need to capture actual rather than potential benefits. After all, we are not interested in what a nice output a firm *could have* produced, but what is its *actual* output.

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## ABSTRACT

This chapter lists ecosystem services and discusses what techniques can be applied in order to assess their economic value.

The last five decades witnessed enormous progress in developing valuation techniques applied to non-market goods (i.e. the goods that do not have market prices). These can be broadly divided into direct and indirect techniques. The former aim at capturing them directly e.g. by asking people "how much they are willing to pay". The latter derive values from observing prices not for the good of interest, but rather for a complementary good whose characteristics shed some light on people's relevant preferences. These techniques were successfully tested in many regions of the world, including Poland. The best known exercise of this sort is the one published by *Nature* in 1997, where an attempt was made to estimate the global economic value of annual ecosystem services. Numerous subsequent studies have allowed for much more accurate assessments. Consequently, researchers addressing valuation problems have an extensive accumulated research experience to rely on.

**Key words:** ecosystem services, valuation techniques.

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