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Innovations in the methodological approach to quantifying and evaluating the supported effects of forests for recreational and educational ecosystem services

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Abstract: The paper deals with a new method of innovative assessment of the supported effects and ecosystem services of forests using the actual amount of their increased costs. Among the most important research findings and significance of the new method is that it contributes to the body of knowledge on valuation and payment for ecosystem services. The focus of the research task is to help address the current difficult economic situation of forest owners resulting from the impacts of climate change. The study aims to determine what work quantifies the amount of compensation for the provision of supported ecosystem services that is sufficient for owners by using hypothesis testing. The evaluation of the supported effects was carried out in a case study in the area of the Chrudim-Podhůra Recreational Forests in the Czech Republic. The results of the evaluation were quantified in two experimental spreadsheets of the results, a comparative analysis of the evaluation results was performed, and hypothesis testing was conducted. The innovative methodological approach to the assessment of supported effects can be easily modified and used to assess the actual amount of increased costs of other ecosystem services of the forest.

Keywords: comparative analysis; compensation for increased costs; forest valuation methods; payments; special-purpose forests; subsidies

The recreational function of the landscape, the natural terrain, and especially the forest are veritably salubrious for individuals and the general public. However, the monetary value of health benefits of recreational functions is difficult to estimate in financial terms. Therefore, a new forest valuation method of analysing not only the value of commercial goods but also the value of benefits to human well-being was developed (Lockwood et al. 2006).

The Millennium Ecosystem Assessment (MEA) was launched by the UN and Global Environmental Facility in 2001 to assess the state of the world's ecosystem services and layout scenarios for their conservation (Reid et al. 2005). The MEA divided the ecosystem services (ES) into provisioning, regulating, and cultural services. In the present study, cultural ES recreational and cultural ES educational (cultural ES RE) are quantified and evaluated according to this classification. We also focus on the Common International Classification of Ecosystem Services (CICES), which is proposed as a universal classification system (Potschin et al. 2011). It developed an indispensable classification that distinguishes only between final ecosystem services, which directly contribute to the goods valued by consumers, and intermediate services, which bolster the absolute services (Boyd, Banzhaf 2007; Fisher, Turner 2008). Recent references are mentioned below.

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The issue of ecosystem services is also part of exploring bioeconomy strategies (Anikwe, Ife 2023). Conditions are defined to determine the significance of each ecosystem service, which is provided to all stakeholders, including citizens. Similar information is essential for perpetuating specific procedures for evaluating operation preferences and in the overall assessment of ecosystem services so that these procedures are transparent and give the opportunity for cooperation.

European forests provide various forest ecosystem services (FES; García-Nieto et al. 2013; Plieninger et al. 2013; Saarikoski et al. 2018). Monetary valuation, or the restatement of physical amounts in financial terms, estimates the total impact on different ecosystem services, allowing comparisons between individual services, costs, and other profitable impacts. As it is not possible to maximise all forest ecosystem services simultaneously, opinions on what forest operation plans and operation practices will look like are the result of trade-offs. The value of forest ecosystem services frequently shows benefits to well-being, so it may be possible to decide on the value from direct benefits. A distinction can be made between use value deduced from the direct or circular use of FES and non-use value deduced from the natural value of ecosystems and their biodiversity (Brockerhoff et al. 2017; Saarikoski et al. 2015; Coscieme, Stout 2019).

The valuation of ecosystem services should be directly identified and estimated as integrative. The issue of integrating different services (especially recreation services) is addressed in numerous studies and can be set up, for illustration, in land-use planning styles (Vasiljevic, Gavrilovic 2019). In particular, the evaluation of geography, geographic rudiments, and information on the number of visitors to study areas leads to better involvement of all stakeholders in spatial planning and in the process of planning new forest ecosystem services (Vasiljevic, Gavrilovic 2019). The concept of transition and the involvement of ecosystem services in cooperative ways of working are among the main ideas of the institutions involved so that this transition leads to a sustainable and adaptive way of working and not only within the framework of environmental problems in society (Loorbach et al. 2010).

In recent decades, the concept of nature and ESs as capital has gained visibility (Schaefer et al. 2015).

By conserving and restoring natural territories, the society can admit important goods and services, such as clean air and water, flood tide control, and crop pollination (European Commission 2019).

The programs that shape the forestry sector are veritably different, and this is also reflected in the power, structure, and approach to addressing and assessing forest ecosystem services. The sectoral programs that intervene in this process are, among other things, in the areas of husbandry, energy, nature conservation, and pastoral development (Pülzl et al. 2018; Primmer et al. 2021; Winkel et al. 2021).

A combination of valuation styles and ways is frequently indispensable to value ecosystem services directly and quickly. What system is chosen and how these functions are valued depends on the specific situation and characteristics of the point, the proprietor, and the information and fiscal resources available.

Most of the operations in the nature value discovered until now are related to demonstrating the value of being nature areas, which are covered by the civic expansion. Exploration shows that involving forest visitors and other stakeholders in the decision-making process (as they tend to be the most sensitive to operational changes in the timber) is veritably applicable and salutary for the coming way in operational changes (Sergiacomi 2022). Recreation opportunity is defined as the capacity of ecosystems to provide recreation according to their scenic beauty or specific characteristics (Peña et al. 2015).

The choice of criteria to predicate opinions is individual, so the first step is to define these and the process by which they are unequivocally named and prioritised (Segura et al. 2015).

The utilitarian approach is naturally linked with cost-benefit analysis and wellness economy since they approach human well-being in terms of individual satisfaction based on the goods and services. At the same time, environmental psychology exploration confirms that the applicability of ESs for human well-being is further than the satisfaction of individual requirements and consists of physical and brain health, social integration, and artistic identity (Baciu et al. 2021).

Methodological factors may significantly impact ES quantification (Eigenbrod et al. 2010; Van der Biest et al. 2015) and are essential query sources in ES assessments (Hou et al. 2013). Forest planning and operation strategies are beginning to include forest ES as crucial rudiments in their assessments (Frank et al. 2015), which can help imagine and promote the multifunctionality of these systems.

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The situation of the owners of each recreational forest area is inherently different. Each forest in a particular location serves a somewhat different range of ecosystem services (non-market environmental, recreational and educational services); thus, it is not possible to determine the value of compensation for increased costs the owners of special-purpose forests are entitled to under Section 36, Paragraph 3 of Forest Act No. 289/1995 Coll. without knowing these specific ecosystem services supported.

The aim of the innovation in the methodological approach to quantifying, evaluating, and enumerating the supported forest effects for recreational and educational ecosystem services in suburban forests was to create a new method of quantifying the amount of compensation for the provision of recreational (social) ecosystem services by quantifying the value of compensation for their increased costs. The quantification of inputs for supporting and maintaining the recreational function of the forest was carried out in a case study of a selected area of the Chrudim-Podhůra Recreational Forests. Another objective of the work was a comparative analysis of the results of the applied procedures to evaluate the socioeconomic significance of the functions of special-purpose forests.

After conducting the new evaluation by the method described in this paper and called 'Method of quantification, evaluation, and enumeration of supported forest effects for the recreational and educational function of forests in special-purpose forests – suburban forests' the values of the supported forest effects in the case study area were also quantified using two other selected methods. Firstly, quantifying the values of the supported forest effects was performed using the methodology commonly used in the Czech Republic and called 'Methodology for evaluating the social, socioeconomic significance of forest ecosystem services' (Šišák et al. 2017). Subsequently, the quantification was performed using the methodology commonly used in Italy 'Quantifying the value of supported forest effects using a method called Assessing, Valuating and Mapping of Ecosystem Services in Alpine Forests' (Häyhä et al. 2015). Finally, the amount of compensation for increased costs was quantified using all three methods. This amount of compensation for increased costs corresponds to the value of the supported forest effects. In monetary terms, it expresses the amount of compensation for providing the supported forest ecosystem services in the form of non-market environmental recreational and educational services in the case study area.

MATERIAL AND METHODS

Chrudim-Podhůra Recreational Forests – Current state of the area case studies, analysis of the management of the area

For the evaluation of the supported effects for recreational and educational functions in special-purpose forests – suburban forests, an area in the Chrudim-Podhůra Recreational Forests was selected. The location of the area within the Czech Republic is shown in Figure 1. According to Forest Act No. 289/1995 Coll., the forest stands are classified as special-purpose forests – suburban forests and other forests with increased recreational function. In the past, there were large-scale economic interventions, repeated clear-cuts, pastoral farming and repeated coppice management and the development of park landscapes. According to the actual Forest Management Plan (Lesprojekt 2020), conifers predominate in the Forest Management Unit with a 68.3% share, while broadleaf trees have a 31.7% share. Of the conifers, Norway spruce and Scots pine are mainly represented, and of the broadleaf trees, beech and oak. The area of the Chrudim-Podhůra Recreational Forests is currently 122.87 ha (Lesprojekt 2020).

Chrudim-Podhůra Recreational Forests are a part of the Slatiňansko-Slavicko Landscape Monument Zone, and the area also belongs to the northernmost spur of the Železné hory Protected Landscape Area.

The area of the recreational forests has been connected with the town of Chrudim since the 14th century. The current development of cultural recreational and educational ecosystem services is a continuation of the association's activities that began to develop the area in the second half of the 19th century.

The year 2004 can be regarded as the first year in the modern history of the Chrudim-Podhůra Recreational Forests because in that year, at the request of the owner, the previously commercial forests were transferred to the category of special-purpose forests – suburban forests and other forests with increased recreational function for the future development of the area (Lesprojekt 2020).

Until 2004, no recreational, educational, and ecosystem service development projects had been

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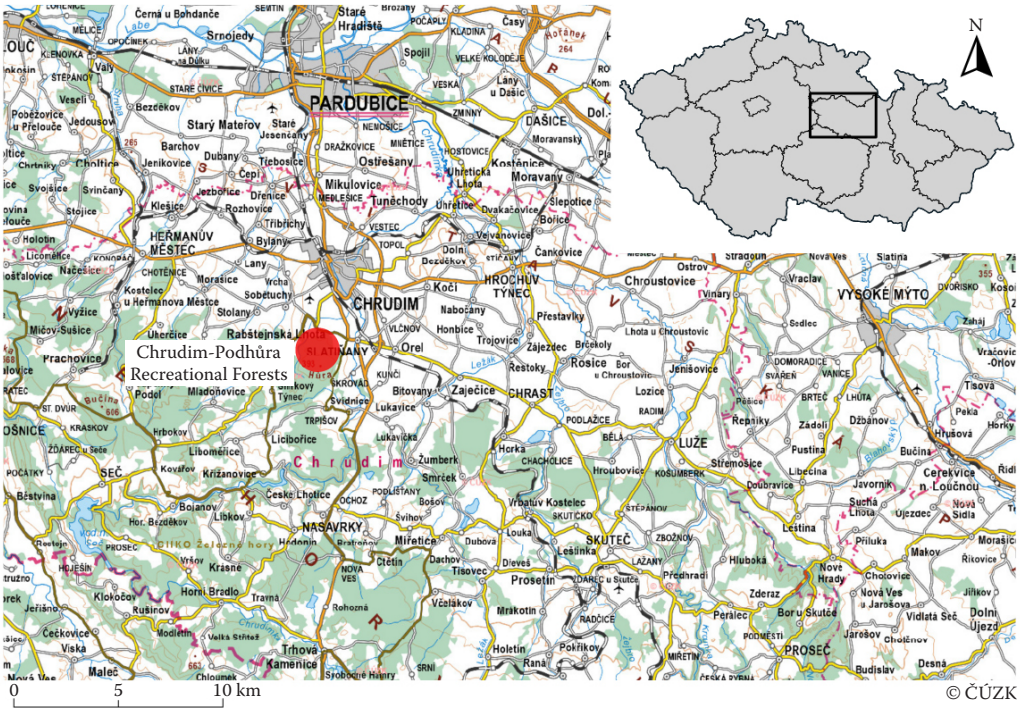

Figure 1. The territory of the Chrudim-Podhůra Recreational Forests on the map of the Czech Republic (ČÚZK 2010)

carried out in the former commercial forests. The analysis carried out indicated that between 2006 and 2022, 27 supported projects of recreational and educational ecosystem service development were implemented with a total value of EUR 1.14 million to improve the quality of recreational service provision. With the implementation of these projects (Figure 2), the area has become the site of one of the most comprehensive and well-equipped recreational forests in the Czech Republic.

No exact statistics on visitor numbers before and after the implementation of the projects were carried out (information on visitor numbers was obtained by the operator's qualified estimates); this issue could be the subject of future research.

The owner leases the area of the Chrudim-Podhůra Recreational Forests to their own company Městské lesy Chrudim, s.r.o. The company manages the area at the centre of the recreational forests.

For clarity, the analyses and results of the management of Městské lesy Chrudim, s.r.o. for the period 2010 to 2022 were divided into two parts, namely, the results of the management of the entire company and the results of the management of the recreational forest centre. Data from the accounts and other records were analysed, mainly concerning subsidies, contributions, projects, investments, maintenance, etc. All the financial data from the analyses and results of the company's financial performance are presented in thousands of EUR without VAT; the conversion to EUR was made according to the Czech National Bank exchange rate of 31 December 2022 of CZK 24.115 per EUR 1.

Based on the analyses, the overall management results of the company Městské lesy Chrudim, s.r.o., between 2010 and 2022 were determined for the valuation of the supported effects of forests using the new method. The revenues and costs, according to the analytical account numbers and the economic result of the centre of the recreational forests, were determined for the period 2010 to 2022.

From the overall economic results, the average results of the management of the total area and per 1 ha of land of Městské lesy Chrudim, s.r.o., and the recreational forest centre were determined. The annual contribution of the forest owner and the average contribution in total and per ha between 2010 and 2022 were also determined. Data from the accounting of Městské lesy Chrudim, s.r.o., were used as a source for calculating the economic results for the period between 2010 and 2022. Based on the company's economic results, the revenues of the recreational forest centre, the expenses of the recreational forest centre,

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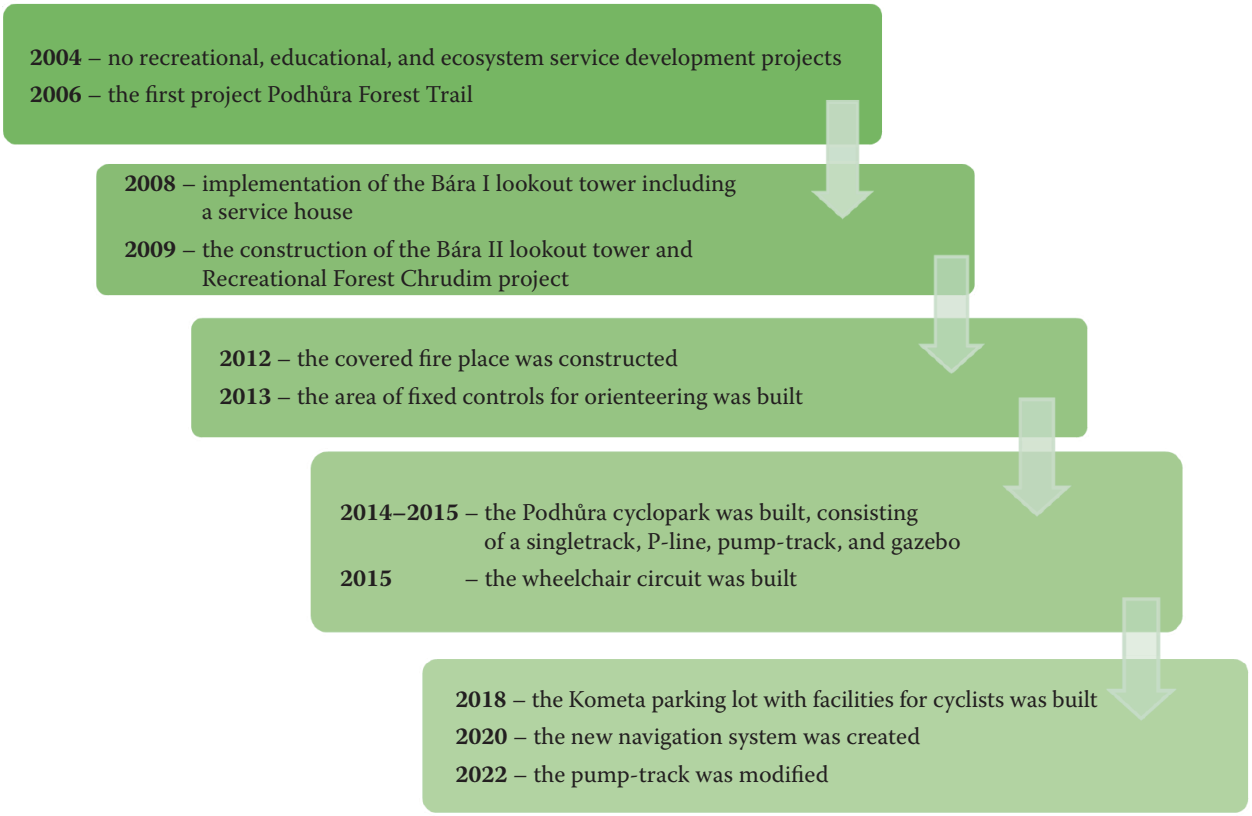

Figure 2. Flow chart of the most important projects in the Chrudim-Podhůra Recreational Forests (own processing)

and the economic results of the recreational forest centre were calculated.

Developing a new valuation method

The newly developed method called Method of Quantification, Evaluation, and Enumeration of Supported Forest Effects for Recreational and Educational Functions of Forests in Special-Purpose Forests – Suburban Forests (MQE method) quantifies and evaluates supported forest effects for recreational and educational functions in the selected area using the actual amount of their increased costs. The new method is described in more detail in the Results section.

Quantifying the value of the supported effects (amount of compensation for providing increased supported cultural ES RE in special-purpose forests – suburban forests) using the new method and the two existing methods

Quantification of the value of supported forest effects using the new MQE evaluation method. The value of the supported effects by quantifying the actual amount of their increased costs was determined using a method established by the procedure described in more detail above.

Quantifying the value of the supported forest effects using a method called Methodology for the Evaluation of the Social and Socioeconomic Significance of Forest Ecosystem Services (MES method). This evaluation method was selected as the method developed in the Czech Republic. In the methodology, the values of health and sanitary, and cultural and recreational functions of the forest are derived in an expert comparative way, based on their relative importance to the importance of production functions, with the subsequent assignment of the price achieved over a specified period in the Czech Republic (Šišák et al. 2017).

This methodology aimed to develop a procedure for assessing the social and socio-economic significance of ecosystem services in monetary terms. The values of ecosystem services in the method are expressed in CZK per ha; the values are expressed in annual amounts in CZK per ha. In this paper, the values in CZK were converted to EUR at the Czech National Bank exchange rate as of 31 December 2022 of CZK 24.115 per EUR 1.

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According to this method, the total amount of compensation for the provision of increased supported ecosystem services in the form of non-market environmental health and sanitary (recreational) and cultural and educational services was determined as the sum of the quantified value of forest health and sanitary services (recreational and health) and the value of forest cultural and educational services (nature conservation, educational, scientific, institutional services).

In the methodology, the values of health and sanitary services and the values of cultural and educational forest services (nature conservation, educational, scientific, institutional) are derived in an expert comparative way, based on their relative importance to the importance of production functions, with the subsequent assignment of the price achieved over a specified period in the Czech Republic (Šišák et al. 2017).

In the methodology, the values of health and sanitary services are included in Chapter II. 3.7 and are divided into forest land with basic visitation and forest land with increased visitation (this category includes suburban forests and forests with increased health and recreational functions). The values of the cultural and educational functions of the forest can be found in Chapter II. 3.8 and are divided into forests used for normal management and forests in landscape and conservation zones (Šišák et al. 2017). The difference between the value of the supported ecosystem service and the basic value can be used to determine the increased value of the supported forest effects, which can be used to determine the amount of compensation for the increased costs of the supported forest effects for the recreational and educational functions of forests in special-purpose forests in suburban forests.

Quantifying the value of supported forest effects using a method called Assessing, Valuating and Mapping of Ecosystem Services in Alpine Forests (AVM method). An international team of scientists from Italy, Sweden, the USA, and Austria developed the second method (currently used abroad). It was applied in 2015 in the Val di Fiemme and Val di Fassa, which are located in the province of Trento in northern Italy. Although the valleys are administratively separated, they can be considered one valley because of the same landscape and geography. The total area of the two valleys is 73 600 ha, with forests covering 39 970 ha (54% of the total area). The main tree species is spruce, which accounts for 80% of the total area; larch, which is found at 10%; and Scots pine and beech, which account for the remaining 10% of the total area. The area is classified as mountainous, and the altitude of the area ranges from 1 000 to 2 600 m a.s.l. The climate is cool with dry winters and cool and rainy summers. The timber from the valley is renowned for its high quality, and wood from the valley was also used for the production of the famous Stradivari violin (Häyhä et al. 2015).

The market price method, the replacement cost method and the contingent valuation-based benefit transfer method were used for the economic valuation of the studied ecosystem services (Häyhä et al. 2015). The benefit transfer method using information transfer from a previous study also conducted in the province of Trento, which also used the contingent valuation approach (Notaro et al. 2008), was used here for the valuation of cultural ecosystem services. Contingent valuation is based on surveys in which people are asked how much they are willing to pay for specific environmental services, but there is no derivation of actual service values. However, the strength of contingent valuation is that it can estimate the non-use values of ecosystem services in monetary terms, not involving market purchases or direct participation. The weakness is that the general public is not sufficiently familiar with ecosystem functions and services. In the study, the recreational and aesthetic value was estimated for the Lavazè forest, covering an area of 99 ha in the upper part of the Fiemme Valley.

Cultural ecosystem services included landscape values and related tourism, hunting and mushrooming. The recreational value of forests in tourism was estimated using the benefit transfer method (Notaro et al. 2008), which updated the results of the previous assessment.

For the valuation of the average economic value of the ecosystem services the name 'Recreation: tourists' was used in the method. For the valuation according to this method, data from the table titled 'Total biophysical amounts, marginal values, average economic values per hectare, and total economic values of ecosystem services in Fiemme and Fassa Valleys' (Häyhä et al. 2015) were used. To quantify the value of the supported effects of cultural services 'Recreation: tourists', the value shown in the column Economic value (EUR per ha per year) was used, which represents the average

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value calculated considering the whole forest area (Häyhä et al. 2015).

Comparative analysis of the results of the methods used to evaluate the supported effects and test the hypothesis

At the end of the paper, a comparative analysis of the results of the three methods used to assess the supported effects is made using an experimental scoring table. The amount of compensation for the provision of increased supported cultural ES RE in special-purpose forests – suburban forests is quantified according to each method and the hypothesis is tested.

RESULTS

Developing a new valuation method

The newly developed method called MQE quantifies, evaluates, and enumerates supported forest effects for recreational and educational functions in the selected area using the actual amount of their increased costs.

The procedure for quantifying the actual amount of the increased costs of the supported forest effects is as follows:

– Step 1. Analysis of the territory, ecosystem services and effects, implemented activities, accounting, and other documents of the selected territory to quantify, evaluate, and enumerate the supported effects for the recreational and educational functions of forests in special-purpose forests – suburban forests to determine the results of the management of the selected territory over a certain period.

– Step 2. Quantification of the actual total annual yields of the supported forest effects of the selected territory.

– Step 3. Quantification of the actual total annual costs of the supported forest effects of the selected area.

– Step 4. Quantification of the actual total annual economic results of the supported forest effects of the selected area.

– Step 5. Quantification of the actual average economic results of the supported forest effects (quantification of the amount of economically incurred costs of the supported effects) for the whole evaluation period for the whole territory and conversion per 1 ha of the selected special-purpose forest area.

– Step 6. Quantification of the possible correction of the average annual economic result of supported forest effects calculated per 1 ha, quantification of the actual average economic result of supported forest effects (quantification of the amount of economically incurred costs of supported forest effects) calculated per 1 ha of the selected area of special-purpose forests after correction.

In case the accounting of a company's operating ecosystem, cultural, recreational, and educational services in the selected territory contains revenues or costs that are not direct revenues of the supported effects of the forest (for example, the owner's general contribution to activities in recreational forests, general subsidies to activities from other sources, etc.), or are not direct costs of supported forest effects (for example, rent for forests, land, etc.), then those revenues or costs will be excluded and removed from the calculation of supported forest effects. These inadmissible returns and costs for calculating the supported forest effect must be clearly identified and calculated (using the procedures established in the previous steps). Finally, any correction of the average annual economic result of the supported forest effects converted per 1 ha will be calculated.

At the end of this step, the actual average economic results of the supported forest effects (calculation of the amount of economically spent costs of the supported forest effects) converted per 1 ha of the selected area of special-purpose forests after correction are calculated using the difference between the average annual economic result of the supported forest effects for recreational and educational functions of forests in special-purpose forests – suburban forests converted per 1 ha (calculated in Step 5) and the amount (calculated in this step) of any correction of the average annual economic result of the supported effects of the forest converted per 1 ha.

– Step 7. Quantification of the actual average economic results of supported forest effects for recreational and educational functions in commercial forests, if any (quantification of the amount of economically incurred costs of supported forest effects) for the whole evaluation period for the whole territory and recalculation per 1 ha of selected economic forest area after correction.

If supported forest effects for recreational and educational functions were implemented in the original commercial forests before the transfer of the

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forests to the category of special-purpose forests in the assessment area, this step will quantify the potential benefits, costs, economic results and corrections of supported forest effects for recreational and educational functions in the management forests using the steps described above. Finally, using the procedure described in Step 6, the actual average economic results of the supported forest effects (quantification of the amount of economically incurred costs of the supported forest effects) are calculated per 1 ha of the selected area of commercial forests after correction.

– Step 8. Quantification of the amount of compensation for increased costs of supported forest effects for the recreational and educational functions in special-purpose forests in suburban forests per 1 ha of the selected area.

Using the difference between the actual average economic results of the supported forest effects calculated in Step 6 (quantification of the amount of economically incurred costs of the supported forest effects) recalculated per 1 ha of the selected area of the special-purpose forests after correction and the amount of the costs of the supported forest effects calculated in Step 7, the quantified actual average economic results of the supported forest effects (quantification of the amount of economically incurred costs of the supported forest effects) recalculated per 1 ha of the selected area of economic forests after correction, the amount of compensation for the increased costs of the supported forest effects for the recreational and educational functions of forests in special-purpose forests in suburban forests per 1 ha of the selected area will be quantified.

Value of the supported effects quantified by the evaluation methods used

The value of the supported forest effects quantified using a new method of evaluation called MQE. The quantification of the supported forest effects of the Chrudim Recreational Forests area was carried out using the procedure described above, see the section 'Developing a new valuation method'.

The economic results of the recreational forest centre of Městské lesy Chrudim, s.r.o., in the years 2010–2022 are quantified in Table 1.

The procedure to quantify the actual amount of increased costs of the supported forest effects:

– Step 1. Analysis of the area, ecosystem services and effects. In the first step, the analysis of the

Table 1. The economic result of the recreational forest centre of Městské lesy Chrudim, s.r.o., between 2010 and 2022 in thousand EUR[1] without VAT

Total economic data	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Annual average[3]	Annual average per ha[4]
Owner's total contribution to activities	21	37	29	33	31	31	21	29	29	29	52	52	29	33	0.269
Total revenues[2]	45	67	56	63	65	71	52	63	63	53	72	61	34	59	0.480
Total costs	65	71	63	80	96	110	85	93	82	75	70	66	45	77	0.627
The economic result (+ profit, – loss)	–20	–4	–7	–17	–31	–39	–33	–30	–19	–22	2	–5	–11	–18	–0.146

[1]Values of the economic results recorded in the company's accounts in thousand CZK were converted to values in thousand EUR according to the Czech National Bank's foreign exchange market rate of CZK 24.115 for EUR 1, as of Dec 31, 2022; [2] total revenues of the recreational forest centre (including the owner's contribution to activities in recreational forests); [3] annual average – annual average for the period from 2010 to 2022; [4] annual average per ha – annual average for the period from 2010 to 2022, as per the area of the Chrudim-Podhůra Recreational Forests, i.e. 122.87 ha

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area and the management of the area was carried out; the results of the analyses are described above in the section 'Chrudim-Podhůra Recreational Forests – current state of the area case studies, analysis of the management of the area'.

– Step 2. Quantification of the total actual annual revenues. The analysis carried out above quantified the total actual annual revenues of the supported effects of the recreational forest centre.

– Step 3. Quantification of the total actual annual costs. The analyses carried out above quantified the total actual annual costs of the supported effects of the recreational forest centre.

– Step 4. Quantification of the total actual annual economic results. The total annual economic results of the recreational forest centre were calculated as the difference between the total annual revenue determined in Step 2 and the total annual costs determined in Step 3 (Table 1).

– Step 5. Quantification of the actual average economic results. The quantification of the actual average economic results for the whole evaluation period for the whole territory was calculated as a loss of EUR 18 000 as the arithmetic average of the total annual economic results of the recreational forest centre for the whole evaluation period.

By dividing the actual average economic results for the whole evaluation period for the whole area (loss of EUR 18 000) and the area of 122.87 ha, the actual average economic result of the supported forest effects per 1 ha of the area was calculated as a loss of EUR 434.

– Step 6. Quantification of the possible correction of the average annual economic result. Due to the forest owner's contribution to the company's activities in the recreational forests, a correction was made to the average economic result. The owner's contribution to the activity amounted to EUR 423 000 for the whole period. The arithmetic average was used to determine the average annual owner's contribution to the recreational forest activity in the amount of EUR 33 000. By dividing the average annual contribution (EUR 33 000) by the recreational forest area of 122.87 ha, the average annual owner's contribution to recreational forest activities for the period was calculated at EUR 269 per ha. The overcorrection of the average annual economic result (reduction in yield) was therefore set at EUR 269 per ha. The amount of the actual average economic result of the supported forest effects (quantification of the amount of economically incurred costs of the supported forest effects) per ha of land after the adjustment of EUR 415 per ha was calculated as the sum of the actual average economic result of the supported forest effects per hectare of land at a loss of EUR 146 per ha, as determined in Step 5, and the adjustment of EUR 269 per ha, as the adjustment was made on the yield side.

– Step 7. Quantification of the actual average economic results of the supported forest effects for the recreational and educational functions in commercial forests. There were no supported forest effects for recreational and educational functions in the commercial forests in the selected area until these forests were transferred to the category of special-purpose forests.

The actual average economic results of the supported forest effects for recreational and educational purposes in the commercial forests (quantification of the economically incurred costs of the supported forest effects) over the whole assessment period for the whole area were, therefore, EUR 0.00. The calculation per 1 ha of the selected area of commercial forests after correction was set at EUR 0.00.

– Step 8. Quantification of the amount of compensation for the increased costs. Using the actual average economic results of the supported forest effects calculated in Step 6 (quantification of the economically incurred costs of the supported forest effects) calculated per ha of the selected area of the special-purpose forests after a correction of EUR 415 and the actual average economic results of the supported forest effects calculated in Step 7 (quantification of the amount of economically incurred costs of supported forest effects) recalculated per 1 ha of the selected area of commercial forests after a correction at the amount of EUR 0.00, the amount of compensation for the increased costs of supported forest effects for the recreational and educational functions of forests in special-purpose forests in suburban forests per 1 ha of the area was calculated at the amount of EUR 415.

In summary, the economic value of the increased supported forest effects for cultural ES RE was determined according to the new MQE method at an annual total of EUR 415 per ha.

Value of supported forest effects quantified using the existing assessment MES method. According to this method, the amount of compensation for the increased costs of supported forest

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effects for the recreational and educational functions of forests in special-purpose forests in suburban forests per 1 ha of the selected area was determined by the sum according to the methodology in Šišák et al. [2017; Chapter II. 3.7 'The value of the health and sanitary services of the forest (recreational and health services)'] at the annual amount of EUR 271 per ha (CZK 6 532 per ha) and according to the methodology in Chapter II. 3.8 'The value of the cultural and educational services of the forest (nature protection services, educational, scientific, institutional services)' at the annual amount of EUR 49 per ha (CZK 1 183 per ha) to the total annual amount of EUR 320 per ha (CZK 7 715 per ha).

The value in recreational forests of the increased supported effects of forest health services (recreational and health functions) according to the methodology in Šišák et al. (2017; Chapter II. 3.7) calculated at the annual amount of EUR 271 per ha was calculated as the difference in the value of forest land with increased visitor services – suburban forests and forests with increased health and recreational functions at the annual amount of EUR 412 per ha (CZK 9 928 per ha) and the value of forest land with basic visitor services at the annual amount of EUR 141 per ha (CZK 3 396 per ha). The value in recreational forests of the increased supported effects of the forest of cultural and educational (nature conservation, educational, scientific, institutional) services (functions) of the forest according to the methodology in Šišák et al. (2017; Chapter II. 3.8) calculated at the annual amount of EUR 49 per ha (CZK 1 183 per ha) was calculated as the difference between the value of forests in landscape and conservation zones at the annual amount of EUR 218 per ha (CZK 5 248 per ha), reduced by a coefficient of 0.5 due to the 5th degree of naturalness, to EUR 109 per ha (CZK 2 624 per ha) and the value of forests serving normal forestry at the annual amount of EUR 120 per ha (CZK 2 882 per ha) reduced by a coefficient of 0.5 to EUR 60 per ha (CZK 1 441 per ha) (Šišák et al. 2017). The naturalness coefficient of 0.5 was used to classify the forests into naturalness level 5 – forests with 50% of geographically non-native tree species, as well as dying, disturbed or heavily vegetated forests of tree species that do not match the habitat (Hort et al. 1995).

Value quantified using the existing assessment AVM method. For the valuation of the supported effects of the studied ecosystem services, a benefit transfer method based on contingent valuation was used. The amount of compensation for the increased costs of the supported forest effects for the recreational and educational functions of forests in special-purpose forests (in suburban forests) per 1 ha of the selected area was quantified by this method using data from the table titled 'Total biophysical amounts, marginal values, average economic values per hectare, and total economic values of ecosystem services in the Fiemme and Fassa Valleys' (Häyhä et al. 2015), the average economic value of the ecosystem cultural service 'Recreation: tourists' is estimated in this table at an annual total of EUR 77 per ha.

Comparative analysis of results, hypothesis testing

As a basis for the proper implementation of the comparative analysis, the experimental results sheet (Table 2) was first prepared, which, according to the individual evaluation methods, shows the values of compensation in EUR per ha for the provision of increased supported cultural ES RE in special-purpose forests – in suburban forests.

The next step of the comparative analysis was to compare and analyse the results of the quantified amount of compensation for services in EUR per ha per year according to the different evaluation methods, both in absolute values and in percentage terms. The arithmetic mean of the annual service compensation amount of EUR per ha per year was calculated according to each assessment method at an annual amount of EUR 271 per ha; the modus is not available, and the median was calculated according to each assessment method at an annual amount of EUR 320 per ha.

The experimental results sheet (Table 2) shows the quantified amounts of the annual compensation of services for the provision of increased supported cultural ES RE – in suburban forests, determined by the work according to single methods of evaluation to test the hypothesis for the area of the Chrudim-Podhůra Recreational Forests in thousand EUR without VAT per territory per year. Furthermore, the value of compensation for the provision of supported forest ecosystem services according to the actual economic results of management (excluding forestry profits and owner's contributions to the activity) in the Chrudim-Podhůra Recreational Forests determined for testing the hypothesis is shown here in thousand

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Table 2. Experimental results sheet – Amount of annual compensation for services according to method in thousand EUR per territory per year, the result of hypothesis testing

Evaluation method; amount of compensation determined for hypothesis testing	Annual service compensation amount (thousand EUR per ha per year)	Chrudim-Podhůra Recreational Forests			
		area (ha)	amount of compensation for services[1] (thousand EUR per territory per year)	amount of compensation for the provision of supported ecosystem services[2] (thousand EUR per territory per year)	result of hypothesis testing
MQE method	0.415	122.87	51	–	H+
MES method	0.320	122.87	39	–	H–
AVM method	0.077	122.87	9	–	H–
Amount of compensation determined for hypothesis testing	–	122.87	–	51	–

[1] The amount of annual compensation for the provision of increased supported cultural ES RE in special purpose forests – in suburban forests, determined by work according to single methods of evaluation to test the hypothesis in the territory of the Chrudim-Podhůra Recreational Forests in thousand EUR without VAT per territory per year; [2] the amount of compensation for the provision of supported ecosystem services of the forest according to the actual economic results of management (excluding forestry profits and the owner's contributions to the activity) in the Chrudim-Podhůra Recreational Forests – determined for testing the hypothesis in thousand EUR without VAT per territory per year; MQE – Method of Quantification, Evaluation, and Enumeration of Supported Forest Effects for Recreational and Educational Functions of Forests in Special-Purpose Forests – Suburban Forests; MES – Methodology for the Evaluation of the Social and Socioeconomic Significance of Forest Ecosystem Services; AVM – Assessing, Valuating and Mapping of Ecosystem Services in Alpine Forests; cultural ES RE – cultural ecosystem services recreational and cultural ecosystem services educational

EUR without VAT per territory per year and the results of the hypothesis testing.

The maximum value of the annual compensation for services of EUR 51 000 per territory per year was determined according to the new MQE method. The second highest value of the annual service compensation of EUR 39 000 per territory per year was determined by the MES method; this value of the service compensation is EUR 12 000 per territory per year, lower than the highest value determined according to the new methodology, compared to the highest value of service replacement, this value is lower by 23.5%.

The lowest service compensation value of EUR 9 000 per territory per year was determined according to the AVM method; compared to the highest service compensation value, this value is 81.5% lower.

The amount of compensation for the provision of supported forest ecosystem services according to the economic results of management (excluding forestry profits and owner's contributions to the activity) in the Chrudim-Podhůra Recreational Forests to test the hypothesis was set at EUR 51 000 per territory per year.

By testing the hypothesis, it was evaluated whether the amount of compensation for the provision of supported forest ecosystem services (the number of the values of supported forest effects) would be sufficient (i.e. the hypothesis would be confirmed) or insufficient (i.e. the hypothesis would be rejected) for the owner of the suburban forests in the selected area of the Chrudim-Podhůra Recreational Forests. Based on the data, the amount of compensation calculated according to the MQE method would be sufficient; the test result was H+, and the hypothesis was confirmed. For the other two assessment methods used, the amount of compensation would be insufficient; the test result was H–, and the hypothesis was rejected for these methods.

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DISCUSSION

The value of compensation for increased costs or supported forest effects is mainly influenced by the choice of the specific methods used for the assessment. There are many valuation methods in use around the world, with the current state of the art most prominently described by the 2021 meta-analysis. In this meta-analysis, a meta-analysis of the economic values of global forest ecosystem services is presented based on data from primary studies published between 1990 and 2018; value estimates from these studies were standardised into a database of 261 eligible primary studies and 758 value estimates or observations. The study reveals large differences in the reported economic values of forests and ecosystem services (Taye et al. 2021).

The wide variation in cultural ES RE scores can be clearly seen in the results of this study. Compared to the results of the highest rating according to the new MQE method, the second highest rating according to the MES method is 23.5% lower, and the lowest value found according to the AVM method is 81.5% lower.

To compare the values of the increased costs of ecosystem services by the method, we should valuate (estimate) these supported ecosystem services at their usual value (usual price). According to Property Valuation Act No. 151/1997, the normal price is the price or value that would be obtained if the same or similar supported forest ecosystem service were provided. However, as is evident from the nature of the variability in the provision of forest ecosystem services, each forest asset that provides a supported service is different. There are differences in the size of the estate, location of the estate, species and spatial composition of the forests, different supported activities, number of activities, etc. To simplify, it will not be easy to find for comparison at least three identical or similar estates that provide the same (similar) supported forest effects.

The issue of quantifying and evaluating the supported effects of forests for recreational purposes is becoming very important for owners of recreational forests due to the current predominantly negative economic situation in forestry. Especially given the impact of climate change on the current forest stands and the resulting economic problems of the entire forestry sector, it can soon be assumed that the owners of recreational suburban forests will not be able to fully cover the costs arising from the fulfilment and development of non-market environmental forest ecosystem services without the market impact of health-hygienic (recreational) and cultural-educational (educational) services, nor to accept the costs of forest management constraints resulting from the fulfilment of these ecosystem forest services. These increased costs are the result of deliberately intensified forest ecosystem services created by active multifunctional forestry based on the demands of society and visitors to these forests. Without the help of support, subsidies, visitor contributions, etc., forest owners will be forced to reduce these services, or at best, owners will not actively develop these services.

Methods of valuing the supported effects are usually based on the valuation of the supported effects of a particular area. They are mostly determined by the willingness of visitors to pay for the supported effects or are calculated as compensation for visitors' travel expenses. These values are determined from questionnaire surveys of visitors, who usually need to gain more knowledge of the actual costs of the supported ecosystem services. Still, these valuations are not based on the specific economic performance of the valued areas. In contrast, the method developed by the work for valuing a specific area using the incremental cost method is based on actual cost data of the area ascertained from accounting records. In testing the hypothesis, the thesis confirmed that the observed value of increased costs corresponds to the actual increased costs of the territory. However, quantifying this value requires a detailed analysis of the economic performance of the territory. As it is clear, the value thus established can only be used for the valuation of this or similar territory. However, the question is whether the valuations established by other methods can be used for the valuation of other areas. Another problem in comparing the total amount of supported effects of the territory in different countries may be different national legislation. The total value of the supported benefits and ecosystem services of the territory is also highly dependent on the individual choice of the extent of post-harvesting of the supported ecosystem services by the forest owner. Some owners will prefer to focus primarily on forest management, while others will support the provision of forest ecosystem services. Nowhere in the forest laws is it specified that the provision of recreational and educational services is an obligation of the owner, nor what scope of ecosystem services the owner must pro-

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vide. Therefore, it is possible that in two nearby areas, the values of compensation for the provided effects will be very different; some owners will want to provide recreational services comprehensively and to the maximum, and some will be satisfied with only a basic set of ecosystem services.

The use of the new MQE method is particularly suitable for owners of recreational forests due to the valuation of cultural ES RE using the actual amount of their increased costs. The owners use this method to determine the actual amount of their increased costs, and, thanks to the corrections used in the method, they can also compare this value with other cultural ES RE providers.

CONCLUSION

The objectives were met, and a new evaluation method was developed. According to the results of the quantified supported effects of forests for recreational and educational ecosystem services using the three established evaluation methods, a comparative analysis was carried out. In testing the hypothesis, it was found that the compensation for the provision of supported ecosystem services according to the method called MES and according to the method called AVM would be insufficient; the compensation calculated according to the new method called MQE in the amount of EUR 51 000 per territory per year would be sufficient for the owner. Finally, the interpretation of the results obtained by the application of the individual methods in the territory of the Chrudim-Podhůra Recreational Forests was carried out.

The new method of assessing the supported effects and ecosystem services using the actual amount of their increased costs is inherently complex and universal. Therefore, the method can be used to valuate other ecosystem services by foreign forest owners. The new method and the results of the evaluation can be used to compare the value of the supported effects between forest owners. They can also be used to determine the level of contributions, subsidies, and payments for the implementation of ecosystem services.

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