QUALITATIVE ASSESSMENT OF ECOSYSTEM SERVICES FOR RECREATION AND TOURISM IN THE SPATIO-TEMPORAL GEOSYSTEM

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Abstract. The paper proposes a comprehensive method of qualitative evaluation of services provided by various providers, which are expressed by characteristics that avoid a quantitative representation. The research foresees the application of the well-known method of deployment of quality functions, the development of which consists of the possibility of determining the coefficients of the weighting of technical characteristics of cultural ecosystem services for recreation and tourism of the spatiotemporal geosystem. To take into account the priority of consumer requirements, the expert method of pairwise comparisons was introduced, which was modified so that possible conclusions could be considered, in particular, the evaluation of the equivalence of characteristics was applied. To obtain the degree of correlation between the characteristics determined by experts based on consumer requirements and the technical characteristics of cultural ecosystem services for recreation and tourism, it is proposed to utilize the fuzzy logic method. Since both the presence of correlations links and the degree of correlation between consumer requirements and technical characteristics are the result of the interaction of a set of various factors, among which a significant number may be random, based on the central limit theorem, as well as the experience of applying correlation coefficients in other areas, a conclusion is drawn, that the probability distribution function of correlation degrees is properly described by a Gaussian curve. The value of the technical characteristics of the specified ecosystem services for three spatiotemporal geosystems was also obtained with the help of the fuzzy logic method.

Key words: Customer requirement; Technical specification; Service; Ecosystem; Quality assessment; Fuzzy logic.

1. Introduction

Ecosystem services (ES) provide the essential resources and benefits which humans can obtain from nature. The satisfaction of fundamental human needs in the environment and food products depends on the ES, and therefore the level of our life directly depends on them. Scientists and politicians in most countries of the world recognize this interpretation. In the UN document "*Millennium Ecosystem Assessment*", ecosystem services are unequivocally called "the direct and indirect contribution of ecosystems to human well-being" [1].

ES can be defined as a set of ecosystem functions that are beneficial to humans [2]. They are the result of auxiliary processes operating at different time and space scales [3]. These general definitions are widely accepted, but the classification of ES and their application to decision-making is accompanied by some uncertainties. In particular, there are different semantic interpretations of the term "ecosystem services", depending on the specific purpose [4]. According to *R. Costanza and Folke*, ES "represents the receipt of human benefits from ecosystem functions (EF), directly or indirectly" [5]. According to the definition of *G. Daily* [6, 7] ES, for which is used the term "services of nature", these are "conditions and processes", as well as "life-supporting functions". The definition of the UN document *Millennium Ecosystem Assessment* [1], which was widespread in studies, is emphasized the direct link between ES and the benefits produced directly or indirectly by ES for humans. Based on the MEA approach, within the framework of the international project 'Economics of Ecosystems and Biodiversity', ES is defined as the direct and indirect contribution of ecosystems to human well-being [8].

J. Boyd & S. Banzhaf [9] propose a dissimilar interpretation of the term. According to them, ES is an ecological component or structure that is directly consumed to create human well-being. Therefore, indirect processes and functions are considered intermediate ecological components. In contrast to the above definition, *Fisher and co-authors* [4] suggest that ES is "certain active/passive applying ecosystems to create human well-being" [4]. Therefore, services cover the organization and structure of ecosystems, as well as processes and/or functions, if they are directly or indirectly consumed by humans.

There are two main reasons why the concept of "ecosystem services" and the related concept of "natural capital" have shown their feasibility in territory management and decision-making. First, they help synthesize other essential ecological and economic concepts, enabling to integration of social and ecological systems. Second, scientists and politicians can propose these concepts to evaluate the economic and political trade-offs between territorial development and biodiversity conservation.

There are three types of ES evaluations, namely: ecological, which is based on indicators of the state of ecosystems; monetary, which can be integrated into decision-making mechanisms, and social, aimed at soci-

ety's perception of ES as a means to avoid possible conflicts and ensure agreed decisions [10].

2. Data Analysis

An analysis of recent advances in the field of ecosystem services studies by a group of experts [11] based on a quantitative synthesis of 153 publications during 1997–2021 showed that 50 % of them were performed in only 6 countries (mainly the USA and China), while the value of ESs there constitutes only 23.5 % of the total value on a global scale. Less than 40 % of the studies used primary observational data, and almost 2/3 of the studies were based on secondary results. The simulation modeling method was rarely considered. In general, less than 1/3 of the works include the raw data for mapping ESs. More than 50 % of issues study the isolated ESs, not considering interrelationships and feedback. Mainly, are identified the following main areas of ES study: obtaining informational data about the environment based on modeling the functioning of ecosystems with feedback, checking the correctness and reliability of the obtained models; comparison of advantages and disadvantages during changes in the types of human and economic activity; consequences for ecosystems located outside the territory – the so-called "external effect"; stakeholder engagement.

Modern social relations are often called a consumer society, which is characterized by the value assessment of any material goods. Therefore, the desire to give a value estimate of the ES is obvious. A comprehensive cost assessment of ESs is too difficult due to their diversity. Therefore, it is appropriate to present ES as a set of subsets of ecological processes and structures. Such analytical work was carried out in the study [12], where 23 functions and related ecological processes and structures were considered and described in detail.

At the same time, considering the concept of sustainable development, authorities need to clearly define and adhere to priorities regarding the consequences of various management decisions in the economic, social, and environmental spheres. In particular, the strategic tasks of Ukraine's development should be aimed at the careful and rational use of natural capital. This requires both an objective assessment of the natural resource potential and the assess the obtained results for alternative options for the economy [13]. When developing strategic programs for its territorial and sectoral development, becomes important to apply complex approaches to the assessment of resource potential, in particular of ES.

The nature of human interaction with the environment is determined by the flows of substances, energies, and information. By changing the value of these flows and humans" actions from the minimally significant to the maximally possible, it is possible to go through many characteristic states of interaction in the "human-environment of functioning system". According to the ecosystem approach based on the multicompartmental concept [14], natural renewable/non-renewable resources should be considered, on the one hand, as the main components of natural capital, on the other – as compartments of the spatiotemporal geosystem (STG). That is, ES are the benefits that a person receives from the STG operation, and they should be interpreted as material, energy, and information flows generated by natural capital reserves in combination with physical (buildings, equipment) and human capital and ensure the well-being of mankind [15].

The mechanism of obtaining ES of an STG consists in the interaction of its compartments, tiers, and subsystems with the atmosphere, water, soil, etc., and in maintaining their qualitative and quantitative parameters at the optimal ecological level for obtaining benefits by consumers. In particular, they include recreation in nature, the health of the body, observation of nature, satisfaction of cultural and cognitive needs, hunting, mushroom and berry picking, and others. In this case, recreation is not commercial but is aimed at meeting the needs of the population for recreation and health improvement [16, 17].

The analysis of the *ISO 9001:2015* and *ISO 14001:2015* standards shows that their requirements for standardizing the quality of STG include, in particular, a thorough study of not only the external and internal environment of STG, a thorough study of not only the external and internal environment of STG but also the application of a process approach to assessing the impact of the main resources of the external environment on the basic processes of ecosystem functioning, such as, for example, photosynthesis and respiration, as well as the development of new methods for assessing the state at which STGs can maintain their integrity and provide ecosystem services under constant influence from technical systems. The mutual influence of different services or changes in the STG itself can have different effects on the provision of their ES. This makes STGs difficult for qualitative evaluation

3. Purpose of the Study

The purpose of the research was to present a method for obtaining an assessment of cultural ecosystem services for recreation and tourism of a spatiotemporal geosystem.

4. Methods of the Study

It is proposed to introduce the expert evaluation, in particular the methods of pairwise com-

parisons and direct evaluation, in combination with the method of *Quality Function Deployment* (QFD) and *Fuzzy Logic* on the example of the evaluation of cultural ES STG of the Carpathian mountain forests. The input data is obtained by surveying a group of experts selected based on their knowledge and experience in the relevant field.

Since the input variables in the traditional application of the QFD method are mostly represented by numerical values and as a result of their processing the received estimates. So, implementation of the QFD method in this study requires a combination of various input data presented in the form of fuzzy linguistic variables, which are rather imprecise and subjective. Therefore, we propose to apply the technique of transforming fuzzy data to obtain more exact data. The human opinions and assessments, the essentiality of connections between various requirements (for example, between consumer requirements and technical characteristics) are mostly expressed in the form of statements, which are characterized by uncertainty. The task was to overcome this vagueness, uncertainty, and, in general, inaccuracy of human statements and solve problems by defuzzification of the collected fuzzy data.

The QFD method [18] consists in building so-called '*Houses of Quality'* (HoQ). HoQ is a formalized representation of the values of various input values, suitable for their processing by a certain algorithm. The appearance of such a 'house of quality' for the high-mentioned goal is shown below (Table 1).

Table 1. Sample HoQ for determining the weighting of quality indicators of cultural ES STGs

The set of characteristics according to the requirements of the consumer {CRi}	The priority of each consumer requirement – *Im*	The set of technical characteristics {TC_j} and their corresponding quantitative values q_j					
		TC_1	TC_2	….	TC_j	….	TC_m
		q_1	q_2	….	q_j	….	q_m
CR_1	Im_1	r_{11}	r_{12}	….	r_{1j}	….	r_{1m}
CR_2	Im_2	r_{21}	r_{22}	….	r_{2j}	….	r_{2m}
….	….	….	….	….	….	….	….
CR_i	Im_i	r_{i1}	r_{i2}	….	r_{ij}	….	r_{im}
….	….	….	….	….	….	….	….
CR_n	Im_n	r_{n1}	r_{n2}	….	r_{nj}	….	r_{nm}
		Weight of each technical characteristic – w_j					
		w_1	w_2	….	w_j	….	w_m

Executing the algorithm provides a complete set of comparative estimates *{w_{jj}}*, which seems to be the weighting factors of technical characteristics and can be used directly or as input data for the next house. The first QFD table is denominated as the first phase or planning matrix.

The method implementation process for each QFD table contains several typical steps. During the construction of the planning matrix, the first step is to identify the customer's requirements. At this stage, the needs of the consumer are determined through the expression of their expectations and priorities, which we will call consumer requirements. For the most part, these are the expected benefits of an object, product, or service, expressed by consumers. Next, try to specify their requirements in the form of an ordered collection and present them with characteristics that describe the consumer's perception regarding requirements (CR)**.** It depends on the experience of the expert team members. The table is filled with data obtained from questionnaires, interviews, or surveys of target groups. The field of characteristics according to the requirements of the consumer of CR_i (Table 1) is represented by values that do not need to be described by quantitative values but only by verbal formulations. Since the ultimate goal here is to determine the priority I_{mi} of each CR_i, it is advisable to apply the appropriate expert evaluation, for example, the method of pairwise comparisons.

The next step is the process of determining the technical requirements for the service. Often they are called measurable because technical characteristics require that they can be determined objectively. Such characteristics are called technical, and in field NoQ (Table 1) they are represented by the area *{TC_{jj}}*. For the evaluation of cultural ESs, part of TC can be represented by physical or other measurable values, and the part, as practice shows, is significantly larger – these values are expressed by linguistic variables. To quantitative represent them, is advisable to apply fuzzy logic.

The TC nomenclature is determined by a multi-disciplinary team of experts perfectly oriented both in the specifics of the object, product, or service and in the methods of TC regulation and determination.

Further filling of the NoQ table consists in obtaining correlations between the characteristics of the CR and TC – the r_{nm} field (Table 1). Experts determine the mutual impact of TCs and characteristics according to consumer requirements. Next, define the weights of TCs, determined by the range of w_j values, located at the base of the quality house (Table 1). Weights are one of the main outputs of HoQ estimated as:

$$w_j = \sum_{i=1}^{n} Im_i \cdot r_{ij}, \quad (1)$$

where r_{ij} is the value of the correlation factor of TC_j with CR_i, I_{mi} is the priority of CR_i.

To combine the opinion of experts' individual decisions, a common presentation of data is necessary. Here, express conclusions in words – fuzzy linguistic variables enabling the consideration of various aspects of human interpretation. Also, experts combine fuzzy linguistic variables with numerous linguistic criteria, such as low, medium, and high-linguistic terms. At the next stage, *fuzzification* is used – the transition from a clear value of some parameter to a fuzzy value of the linguistic variable. To carry out such a transition, the function of the belongingness of the values of the linguistic variable to the fuzzy set A is necessary. The process of fuzzification consists of the early collection of expert information and its processing to build the functions belonging to the input values [19]. The purpose of fuzzification is to establish correspondence between the specific value of a separate input variable of the system of fuzzy logical inference and the value of the membership function of the corresponding term of the input linguistic variable. As a result of fuzzification, specific values of the membership functions for each linguistic term of the system of fuzzy logical inference are established for input variables.

By the fuzzy set A we mean the set of ordered pairs consisting of elements x of the universal set X and their corresponding degrees of belonging $\mu_A(x)$: $A = \{(x, \mu_A(x)) | x \in X\}$. $\mu_A(x)$ is a membership function (characteristic function), indicating how to what degree element x belongs to the fuzzy set A [20]. The function $\mu_A(x)$ takes individual values among a certain linearly ordered set M. The set M is called the set of degrees of belonging. Often the segment [0, 1] is chosen as M. If M contains only two elements, i.e. $M = \{0, 1\}$, then the fuzzy set is interpreted as a clear set. Let A be a class of objects with an uncountable set of degrees of belonging and be normal, i.e. its height $\sup_{x \in X} \mu_A(x) = 1$. Then a certain membership function can be introduced for A triangular, trapezoidal, S- and Z-shaped, sigmoidal, U-shaped, in particular Gaussian, and singleton functions are most often applied [21].

Next, defuzzification is performed which is the procedure of transforming the values of the fuzzy set A into clear values according to the degree of belonging. In the approach of fuzzy sets, the defuzzification procedure is analogous to finding the location characteristics – mathematical expectation, mode, median – of random variables in the probability approach [22]. So, defuzzification is the process of obtaining an estimate of a fuzzy number, which is characterized by its shape, scale, height, and relative location on the x-axis. The transformation of fuzzy data into clear data is carried out through fuzzy composition procedures. By determining the left and right values, the maximum and minimum fuzzy numbers are obtained. According to membership functions of fuzzy numbers, the overall value is defined as a weighted average.

In the case of correlations between the characteristics according to CR and TC for the "house of quality" (Table 1), their values are obtained from the formula: $\bar{r} = \sum_{k=1}^{l} r_k \mu(r_k) \Big/ \sum_{k=1}^{l} \mu(r_k)$ which characterizes decision-making based on the conclusions of k = 1, 2, ... l experts according to the vague estimates of each k-th expert about the degree of influence of criterion j – technical characteristics on criterion i – consumer demand.

It is expedient to present the result of the implementation of the method on the example of obtaining qualitative evaluations of several providers of cultural ES STG for their comparative characteristics [23]. The qualitative assessment is made by:

$$U = F(w_1 q_1, w_2 q_2, ..., w_j q_j, ..., w_{m-1} q_{m-1}, w_m q_m), \quad (2)$$

where F is a function that combines a set of q_j – TC values, considering their weights w_j. For example, for arithmetic summation, formula (2) changes to:

$$U = \frac{\sum_{j=1}^{m} w_j \cdot q_j}{\sum_{j=1}^{m} w_j}. \quad (3)$$

Experts with experience in the relevant field should be selected to collect data and obtain initial estimates. Managers, quality engineers, and representatives of service users can be experts.

5. Determination of consumers' requirements

Determining consumers' requirements consists in forming by experts a list of quality established characteristics based on the results of a survey of representatives of users of cultural EPs STG and establishing degrees of their significance – a priority for the consumer. According to experts' assessments, a list of nine characteristics was determined that reflect the consumer's requirements for the quality properties of cultural ESs (Table 2).

Table 2. Demands of consumers and CRC to cultural ES of the Carpathian mountain forests

No.	Consumer requirements	The name of the CRC	Designation
1	A comfortable climate	The physical and geographical characteristics of the territory are close to comfortable ones	RES(1)
2	Access to interesting objects	The level of accessibility to the natural and historical and cultural potential of the territory	RES(2)
3	A favorable geographic location	The level of costs for access to the service	RES(3)
4	Absence of dirt and garbage	The degree of pollution of environmental components	RES(4)
5	Beautiful and diverse landscapes	The degree of attractiveness of landscapes	RES(5)
6	The attractiveness of cultural objects	The level of aesthetic properties of objects	RES(6)
7	The uniqueness of cultural objects	The presence of objects of world significance entered into the protection lists	RES(7)
8	Safe location	The level of recreational development of the territory	RES(8)
9	Conditions for active tourism	The degree of provision of faunal and floristic resources	RES(9)

Table 3. Pairwise comparison matrix filled in by Expert 1

Characteristics according to CR	Characteristics according to CR									E^1 – frequency of predominance of the characteristics in a row over the characteristic in a column
	RES(1)	RES(2)	RES(3)	RES(4)	RES(5)	RES(6)	RES(7)	RES(8)	RES(9)	
RES(1)	–	2	1	1	5	1	7	1	1	5
RES(2)	–	–	2	2	2	2	27	2	2	6.5
RES(3)	–	–	–	4	5	36	7	38	3	2
RES(4)	–	–	–	–	45	46	7	4	4	3
RES(5)	–	–	–	–	–	5	7	5	5	3
RES(6)	–	–	–	–	–	–	7	6	9	1
RES(7)	–	–	–	–	–	–	–	7	7	2
RES(8)	–	–	–	–	–	–	–	–	8	1
RES(9)	–	–	–	–	–	–	–	–	–	0
E^2 – frequency of predominance of the characteristics in the column over the characteristics in the row	0	1	0	1	2.5	1	5.5	0.5	1	

Table 4. Cumulative frequency of predominance of essentiality e_{i1} of each i-th VSC according to Expert 1

No.	The name of the CRC	E^1_{i1}	E^2_{i1}	e_{i1}
1	The physical and geographical characteristics of the territory are close to comfortable ones	5	0	5
2	The level of accessibility to the natural and historical and cultural potential of the territory	6.5	1	7.5
3	The level of costs for access to the service	2	0	2
4	The degree of pollution of environmental components	3	1	4
5	The degree of attractiveness of landscapes	3	2.5	5.5
6	The level of aesthetic properties of objects	1	1	2
7	The presence of objects of world significance entered into the protection lists	2	5.5	7.5
8	The level of recreational development of the territory	1	0,5	1,5
9	The degree of provision of faunal and floristic resources	0	1	1
		23.5	12.5	36

Currently, is proposed to determine the priority – Im_i CR using the expert method of pairwise comparisons [24]. The method is modified so that it is possible to consider the expert's possible conclusions, in particular, to apply, based on the results of the comparison of characteristics, an assessment of their equivalence. N=7 experts who participated in the evaluation, directly surveyed and processed the wishes of service users. Each of them independently filled out their separate matrix. An example of a matrix filled out by an expert is shown in Table 3. After processing the data of all matrices, the averaged data for the entire population of experts was obtained.

The results of processing the assessments made by Expert 1 (according to Table 3) of the frequency of predominance of individual characteristics formed by the CR over adjacent ones during the provision of the ES of the spatiotemporal geosystem of the Carpathian mountain forests are presented in the Table 4.

As a result of a precise analysis of experts' opinions (total frequency e_{ij} for each characteristic), it is possible to determine the average total frequency e_i for the i-th characteristic using the formula:

$$e_i = \frac{\sum_{j=1}^{N} e_{ij}}{N}, \quad (4)$$

where e_{ij} is the total frequency of predominance of characteristics according to the data of an individual expert; N is the number of experts and, accordingly, the pairwise comparison matrix. After surveying each expert and processing 7 matrices, a summary table of the prevalence of all characteristics was created (Table 5).

The next step consists in calculating the priority coefficients M_i for each of the identified characteristics. The total number of pairwise comparisons conducted by each expert is:

$$y = \frac{n(n-1)}{2}, \quad (5)$$

where n is the number of characteristics. The priority coefficient of each of the identified characteristics is defined by:

$$M_i = \frac{e_i}{y}, \quad (6)$$

where e_{ij} is the total frequency; y is the total number of pairwise comparisons conducted by each expert. The obtained data are presented in Table 6.

Table 5. Summarized table of the total frequencies of CRC according to the survey of 7 experts

No.	The name of the CRC	e_{i1}	e_{i2}	e_{i3}	e_{i4}	e_{i5}	e_{i6}	e_{i7}	e_i
1	The physical and geographical characteristics of the territory are close to comfortable ones	5	6.5	7	6.5	5	5	5	5.71
2	The level of accessibility to the natural and historical and cultural potential of the territory	7.5	7	7	7.5	7.5	7	6	7.07
3	The level of costs for access to the service	2	2	1.5	2.5	3	2	3	2.29
4	The degree of pollution of environmental components	4	5.5	4	3.5	4	5	4	4.29
5	The degree of attractiveness of landscapes	5.5	4	4	4,5	5	5	6	4.86
6	The level of aesthetic properties of objects	2	3	3	2	2	2	3	2.43
7	The presence of objects of world significance entered into the protection lists	7.5	6.5	6.5	7	7	7	6	6.79
8	The level of recreational development of the territory	1.5	1.5	2	1.5	1.5	2	1	1.57
9	The degree of provision of faunal and floristic resources	1	0	1	1	1	1	2	1
	Total	36	36	36	36	36	36	36	36

Table 6. Priority coefficients M_i of each CRC

No.	The name of the CRC	e_{ij}	e_i	M_i
1	The physical and geographical characteristics of the territory are close to comfortable ones	40	5.71	0.16
2	The level of accessibility to the natural and historical and cultural potential of the territory	49.5	7.07	0.20
3	The level of costs for access to the service	16	2.29	0.06
4	The degree of pollution of environmental components	30	4.29	0.12
5	The degree of attractiveness of landscapes	34	4.86	0.13
6	The level of aesthetic properties of objects	17	2.43	0.07
7	The presence of objects of world significance entered into the protection lists	47.5	6.79	0.19
8	The level of recreational development of the territory	11	1.57	0.04
9	The degree of provision of faunal and floristic resources	7	1	0.03
	Total	252	36.01	1

The values of priority M_i from the last column of Table 6 are handled in the future to calculate the weighting coefficients of technical characteristics.

Next, the correlations between the characteristics according to CR and TC were determined. During the formation of the list of technical characteristics, each expert determines what are the qualitative and quantitative factors that characterize the ability of the STG to properly provide the necessary ES, and which can be introduced for its evaluation. The determined TCs are shown in Table 7.

Next, the results of the assessment by experts of the degree of correlation of the characteristics determined according to the requirements of the consumers – CRC, and the technical characteristics of the cultural ES of STG are presented. For this purpose, each expert applied a universal scale to assess the mutual influence of TC and CRC. The experts were asked to combine the vague linguistic variable "correlation coefficient of CRC and TC" with a specially developed set of linguistic terms. The developed totality most fully covers the gradation of possible evaluations and makes it possible to effectively move from vague to clear evaluations with the help of the membership function.

Table 8 presents the linguistic terms of the variable "correlation coefficient of CRC and TC" and their corresponding fuzzy numerical values.

Table 9 shows an example of the assessment of correlations between TC and CRC by one expert using the scale of linguistic terms of the variable "correlation coefficient" given in Table 8.

Since the presence of correlations and the degree of correlation between CRs and TCs are the result of the interaction of a set of various factors, among which a significant number may be random as well as the experience of applying correlation factors from other areas, it can be assumed that the probability distribution function of correlation degrees is described by a Gaussian curve. That is, most of the correlation relations acquire values that are in the interval ($0.3 < r < 0.7$), which means that they are close to the middle of the range.

The results of processing the fuzzy set of verbal ratings from 7 experts are based on the data provided in Table 8 and the proposed membership function is presented in Table 10.

Table 7. TC of cultural ESs of the spatiotemporal geosystem

No.	The name of the technical characteristic	Designation
1	The attractiveness of cultural ESs (qualitative characteristics)	Sp(1)
2	The contrast of the territory of the public housing development (qualitative characteristic)	Sp(2)
3	The number of cultural objects (quantitative characteristics)	Sp(3)
4	Originality (uniqueness) of objects (qualitative characteristics)	Sp(4)
5	Diversity of natural recreational resources (qualitative characteristics)	Sp(5)
6	Use of traditions and tourist and recreational heritage of the STG region (qualitative characteristics)	Sp(6)
7	Availability of nature reserve fund objects (qualitative characteristics)	Sp(7)
8	Compartmental mosaicity of phylogenesis on the territory of STG (qualitative characteristics)	Sp(8)

Table 8. Linguistic terms and their corresponding fuzzy values for determining the correlation coefficients of CRC and TC

	A linguistic term	Fuzzy numerical value
(F)	Full	(0.95, 1.00)
(VH)	Very high	(0.85, 0.90, 0.95)
(H)	High	(0.75, 0.80, 0.85)
(NMNH)	Neither medium nor high	(0.65, 0.70, 0.75)
(AA)	Above average	(0.55, 0.60, 0.65)
(M)	Medium	(0.45, 0.50, 0.55)
(BA)	Below average	(0.35, 0.40, 0.45)
(NMNL)	Neither medium nor low	(0.25, 0.30, 0.35)
(L)	Low	(0.15, 0.20, 0.25)
(VL)	Very low	(0.05, 0.10, 0.15)
(O)	Missing	(0.00, 0.05)

Table 9. An example of linguistic assessments by an individual expert of the degree of correlation between TC and CRC

	Sp(1)	Sp(2)	Sp(3)	Sp(4)	Sp(5)	Sp(6)	Sp(7)	Sp(8)
RES(1)	O	C	NMNL	HC	HC	VL	O	O
RES(2)	O	VL	NMNL	NMNL	VL	AA	VL	H
RES(3)	H	NMNL	VL	O	O	O	O	O
RES(4)	VL	L	AA	VH	H	H	AA	O
RES(5)	F	AA	VL	NMNL	NMNL	BC	NMNL	NMNL
RES(6)	NMNL	NMNL	NMNL	C	H	VL	VL	VH
RES(7)	VL	H	VH	L	O	O	C	VH
RES(8)	L	BA	BA	O	O	O	O	NMNL
RES(9)	VH	VH	C	VL	O	O	O	VL

Table 10. The results of the calculation of the degree of correlation between TC and CRC

	Sp(1)	Sp(2)	Sp(3)	Sp(4)	Sp(5)	Sp(6)	Sp(7)	Sp(8)
RES(1)	0.08	0.41	0.33	0.39	0.37	0.08	0.05	0.00
RES(2)	0.00	0.04	0.59	0.31	0.07	0.61	0.45	0.86
RES(3)	0.21	0.69	0.07	0.00	0.00	0.00	0.05	0.02
RES(4)	0.13	0.59	0.10	0.85	0.81	0.68	0.30	0.71
RES(5)	1.00	0.61	0.05	0.55	0.79	0.57	0.29	0.70
RES(6)	0.25	0.40	0.62	0.48	0.85	0.10	0.07	0.88
RES(7)	0.12	0.60	0.95	0.24	0.00	0.05	0.55	0.91
RES(8)	0.20	0.38	0.44	0.00	0.00	0.09	0.40	0.28
RES(9)	0.91	0.78	0.55	0.11	0.00	0.00	0.10	0.12

Table 11. "House of quality" for determining the importance of TC cultural ES of the Carpathian mountain forests

Characteristics according to the consumer requirements – CRC	The priority of each consumer requirement is *Im*	A set of technical characteristics {TX$_j$} and their corresponding quantitative values q_j							
		Sp(1)	Sp(2)	Sp(3)	Sp(4)	Sp(5)	Sp(6)	Sp(7)	Sp(8)
		q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8
RES(1)	0.16	0.08	0.41	0.33	0.39	0.37	0.08	0.05	0.00
RES(2)	0.20	0.00	0.04	0.59	0.31	0.07	0.61	0.45	0.86
RES(3)	0.06	0.21	0.69	0.07	0.00	0.00	0.00	0.05	0.02
RES(4)	0.12	0.13	0.59	0.10	0.85	0.81	0.68	0.30	0.71
RES(5)	0.13	1.00	0.61	0.05	0.55	0.79	0.57	0.29	0.70
RES(6)	0.07	0.25	0.40	0.62	0.48	0.85	0.10	0.07	0.88
RES(7)	0.19	0.12	0.60	0.95	0.24	0.00	0.05	0.55	0.91
RES(8)	0.04	0.20	0.38	0.44	0.00	0.00	0.09	0.40	0.28
RES(9)	0.03	0.91	0.78	0.55	0.11	0.00	0.00	0.10	0.12
		The calculated weight of each technical characteristic							
		0.2466	0.4457	0.4515	0.3804	0.3326	0.3106	0.3031	0.5987
		Normalized weightings of technical characteristics – w_j							
		0.0803	0.1452	0.1471	0.1239	0.1084	0.1012	0.0988	0.1951

Defuzzification was performed by executing the method of the center of gravity according to the formula:

$$\overline{r}_{ij} = \frac{\sum_{k=1}^{7} \left(r_{ij}\right)_k \mu\left(r_{ij}\right)_k}{\sum_{k=1}^{7} \mu\left(r_{ij}\right)_k},$$

where $\overline{r}_{ij}$ is the average weighted factor of pairwise correlation between the *i*-th characteristic of the CR and the *j*-th TC, determined according to the assessments of 7 experts; $\left(r_{ij}\right)_k$ is the fuzzy estimate of the pairwise correlation factor between the *i*-th characteristic of the CR and the *j*-th TC, determined by the *k*-th expert; $\mu\left(r_{ij}\right)_k$ is the value of the membership function for the fuzzy estimation of the pairwise correlation factor determined by the *k*-th expert. Table 11 presents the results of the determination of TC weight.

After obtaining the normalized TC weighting values, which are the weighting factors of each technical characteristic of the cultural ES of STG, it is possible to obtain qualitative assessments of various spatiotemporal geosystems. It was proposed earlier to consider 3 conditional STG – A, B, and C, which provides cultural ecosystem services to consumers as service providers. To form linguistic assessments for each TC, experts were offered a different term set, which makes it possible to combine technical characteristics different in nature (Table 7). The used linguistic terms and their corresponding fuzzy numbers are listed in Table 12.

When nothing is known about the nature of changes in TC values and there is a need to combine heterogeneous TCs, it is advisable to use the triangular membership function [25, 26]. In this case, the vague event is described by the parameters α, β, γ : α is the smallest possible value, β is the most promising value (the value on the numerical scale that best characterizes the corresponding meaning of the linguistic term) and γ is the most possible value.

The results of evaluation by a separate expert for all TCs of each of the three compared spatiotemporal geosystems are shown in Table 13.

Table 12. Linguistic terms and their corresponding fuzzy values for obtaining expert evaluations of TC

	Linguistic term	Fuzzy number
(VH)	Very high	(8, 9, 10)
(H)	High	(6, 7, 8)
(M)	Medium	(4, 5, 6)
(L)	Low	(2, 3, 4)
(VL)	Very low	(0, 1, 2)

Table 13. An example of linguistic assessment by an individual expert of TC values of spatiotemporal geosystems A, B, C

	Sp(1)	Sp(2)	Sp(3)	Sp(4)	Sp(5)	Sp(6)	Sp(7)	Sp(8)
A	VH	M	L	H	M	H	H	L
B	M	VH	H	VH	M	H	H	M
C	L	H	L	VH	H	M	VH	VL

Defuzzification contains a five-step algorithm [25].

1. Normalization. We determine the range of values that a fuzzy variable can take among the estimates of the *j*-th TC by all *l*=1, 2, ... *k,* ..., seven experts:

$$\Delta = \max \gamma_j - \min \alpha_j. \quad (7)$$

We perform the normalization of each evaluation parameter of the *k*-th expert:

$$\alpha_j^N = \left(\alpha_j - \min \alpha_j\right)/\Delta, \quad (8)$$

$$\beta_j^N = \left(\beta_j - \min \beta_j\right)/\Delta, \quad (9)$$

$$\gamma_j^N = \left(\gamma_j - \min \gamma_j\right)/\Delta. \quad (10)$$

2. We calculate the left (*l*) and right (*r*) normalized values:

$$\alpha l_j^N = \frac{\beta_j^N}{1+\beta_j^N - \alpha_j^N}, \quad (11)$$

$$\gamma r_j^N = \frac{\gamma_j^N}{1+\gamma_j^N - \beta_j^N}. \quad (12)$$

3. We calculate the total normalized clear value:

$$N_j = \frac{\alpha l_j^N \left(1-\alpha l_j^N\right) + \left(\gamma r_j^N\right)^2}{1-\alpha l_j^N + \gamma r_j^N}. \quad (13)$$

4. We calculate the exact value of the *j*-th TC of the *k*-th expert:

$$q_j = min\alpha_j + \Delta N_j. \quad (14)$$

5. We combine clear values in the form of an average according to the estimates of all *l* experts:

$$\overline{q}_j = \frac{1}{l}\left(q_j^1 + q_j^2 + ... + q_j^k + ... + q_j^l\right). \quad (15)$$

The results of the defuzzification of fuzzy linguistic evaluations obtained from 7 experts for each technical characteristic and each studied STC are summarized in Table 14.

Table 14. Results of the evaluation of spatiotemporal geosystems A, B, and C by experts for each TC

	Sp(1)	Sp(2)	Sp(3)	Sp(4)	Sp(5)	Sp(6)	Sp(7)	Sp(8)
A	8.531	5.501	3.035	6.174	4.411	6.907	7.181	2.891
B	6.282	8.147	6.168	7.551	5.991	7.912	6.921	5.750
C	3.825	6.011	3.312	7.276	8.172	4.553	9.573	1.101

Formula (3) was applied to obtain the final assessment which is to compare the spatiotemporal geosystems A, B, and C, which provide cultural ESs. Table 15 shows the final results of the evaluation of each spatiotemporal geosystem providing cultural ESs.

Table 15. Qualitative evaluations of three STGs providing cultural ESs

Spatio-temporal geosystem	Assessment
A	5.1458
B	6.8414
C	5.0759

5. Conclusions

The complexity and multifacetedness of the components of the tourist and recreational potential of the spatiotemporal geosystem and the possibility of its use for the development of tourist activities, in particular in the Carpathian mountain forests, require the formation and improvement of universal methodological approaches to the comprehensive assessment of resources. An alternative comprehensive method of assessment and selection of a provider of cultural ecosystem services for recreation and tourism, which can be different spatiotemporal geosystems, is considered. It takes into account impact factors: landscape complexes, compartments, and their horizontal heterogeneity – mosaicity, faunal and floristic resources, objects of the nature reserve fund, historical and cultural objects, traditions and tourist and recreational heritage of the region, etc. determining the reliability of a qualitative assessment.

Since the resources of the spatiotemporal geosystem should be differentiated following the emerging needs and demands of consumers the approbation of the method of complex qualitative assessment of the tourist and recreational potential (on the example of the STG of the Carpathian Mountain Forests) was considered. This approach combines various methods of evaluating tourist resources, to adjust criteria and technical characteristics, weighting factors, and quality indicators.

It should be added that the systematic solution of problems related to the use of the tourist and recreational potential of the public housing estate for the implementation of cultural ecosystem services requires the improvement of legislation in the field of tourism, the formation of institutional conditions for its sustainable development, the creation of favorable conditions for the work of small businesses, the provision assistance in the training of personnel for the tourism industry and stimulation of demand for the domestic tourism product.

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