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Research Article

DECISION SUPPORT SYSTEM FOR ECOSYSTEM SERVICESMARKET BASED ON MULTI - APPROACH APPLICATION

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Thispublicationdeals with creation of DSS forecosystem services (ES). A number oftheoretical methodologies have beenexplored.Threeof them as application of Multicriteria Analyses based on fuzzy logic, Value based Model, and Artificial Neural Networks have been selected and studied. Based on common theory of that methodologies the authors have developed their own algorithms and software implementation. The implementation results based on the theory of applied methodologies were illustrated with real cases. Hereby, an ecosystem services management paradigm, based on the use of each of the described approaches as well as the continuous feedback monitoring in the implementation of a specific ecosystem service delivery program, was demonstrated.

INTRODUCTION

The current definition of ecosystem services as "The contribution of ecosystem structures and functions, combined with other elements, to human well-being" (Burkhard *et al*. 2012 ab, 2013, 2017) includes both the contribution of the natural environment and the anthropogenic impacts and human contribution for the welfare of the community. The explanation "in combination with other elements" covers changes in nature as a result of human activities - engineering facilities, agricultural crops, agro forestry systems (including forest belts), changes in land use, intensification, etc., which nowadays have reached considerable proportions and lead to a significant change in the natural functions of nature, especially in industry and agriculture. The methodology and classification of ecosystem services were developed in the Millennium Ecosystem Assessment (MEA, 2005) and later publications (de Groot *et al*. 2002). In MEA, the services of forest ecosystems are listed in the following order: food, wood, drinking water, fuel, regulation of water flow, regulation of diseases, carbon sequestration, regulation of local climate, medicine, recreation, aesthetics and cultural.

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The classification of ecosystem services is not uniform and changes over timedepending on the objects and objectives of the inventory.

According to the typology proposed by Kandziora *et al*. (2013), ecosystem services are grouped into 4 groups: regulating, provisioning, cultural and supporting.According to the United States Environmental Protection Agency (US EPA), forest ecosystem services are subdivided into the following groups: environmental (including mainly forest regulatory and support functions); economic (mainly provisioning benefits and services); sociocultural (the forest as a home of millions of people, the strong cultural and spiritual attachment of the people to the forests), as well as the value of the forest as a picturesque landscape (a range of services related to the ideas of aesthetics and beauty for the inhabitants, based on which ecotourism functions, etc.). An EU-wide up-to-date classification (CICES) has been published on the website of the European Environment Agency. Human society's dependence on ecosystem services, including natural resources, is steadily growing, while practices for managing and using these services and resources are leading to environmental degradation, and loss of ecosystems and biodiversity (Leon and de Groot 2012). Today Ecosystem Services is a well-defined and sufficiently active interdisciplinary scientific field that maintains its organizations, platforms and specialized journals. There are an extremely large number of organizations at national and international level that are relevant to environmental, economic or social aspects of biodiversity and ecosystem services. E.g. the worldwide network - Ecosystem Services Partnership (ESP, 2009; https://www.es-partnership.org/) with 48 environmental organizations, universities, companies, etc .; The European Commission adopting “A strategy for Biodiversiry 2020” (2011) and setting up a special Working Group on Mapping and Assessment on Ecosystems and their Services (MAES, 2012; https://biodiversity.europa.eu/maes); Rio+20 outlines the vision for a “Green Economy (UN, 2012)”, which recognizes that economic performance depends on the effective management of ecosystems and biodiversity and on the sustainability of ecosystem services; The International Finance Corporation (IFC, 2012, UN), which publishes revised “Performance Standards” on environmental and social sustainability; Economics of Ecosystems and Biodiversity - TEEB2 (http://www.teebweb.org/about/the-initiative/), developing concepts and methodology for the evaluation and evaluation of ecosystem services. The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, 2012; https://www.ipbes.net/) provides mechanisms for assessing, integrating and analyzing knowledge and information that are consistent with both the scientific community and management structures. Open NESS and OPERA (Seventh Framework Program, 2015) and ESMERALDA (http://www.esmeralda-project.eu/) have contributed to the development of the concept and methodologies for ecosystem services evaluation and valuation. Assessments of the state of bioresources and ecosystem services are essential to support decision-making. However, adequate assessment requires both an integrated approach and the development of applications to support decisions regarding the use of the provided services (Maes *et al*. 2012, Lyubenova *et al*. 2015 ab, Lyubenova *et al*. 2016, Chikalanov *et al*. 2016, 2019 and others.). Such decision-making process can determine which set of services is most valued and achieves system sustainability. In a narrow sense, the sustainability of the production of an ecosystem service can only relate to whether the biological potential of the ecosystem can sustain the same yield of that service. Combining new technologies from the digital age can facilitate the creation of effective and sustainable resource management by developing a program for choosing and facilitating the right decisions.In-depth analysis of existing DSS has been made byBagstad *et al*. (2013) The authors have conducted research and implemented DSS software in the three main areas Multicriteria Analyses based on fuzzy logic, Value based Modeland Artificial Neural Networks.

METHODS

As a result of research on existing DSS, three approaches for developing DSShavebeen selected asApplication of multi-criterion analysis based on fuzzy sets, use of expertise and application of artificial neural networks. The use of multi-criterion analysis based on fuzzy sets is convenient in cases, where a finite number of alternatives evaluated by several criteria are known. The developedapproach wasbased onPeneva and Pochev (2006, 2007) and algorithm was implemented in JAVA.

In many cases the application of modeling based on expert knowledge is s an applicable approach for building decision-making systems (Bagstad *et al*. 2013, Pavlov and Andreev 2013). The Value Based Model (VBM) provides such an opportunity. The appliedapproach was based on stochastic programming and the Utility theory (Keeney and Raiffa 1999). The Utility theory basically deals with the expressed subjective preferences. Possible criteria for "the meaning of best" can be an expert (decision maker -DM) utility function (Pavlov and Andreev 2013). The developed model was implemented in MATLAB.

The methodology for data processing by means of Artificial Neural Networking based on estimated time series was applied.

RESULTS AND DISCUSSION

Application of multicriteria analyses based on fuzzy logic (MA)

Let’s assume that we have a set of n forest-based solutions, each one with different impact on forest ecosystem and different total cost. The decision maker’s objective is to select the most cost-effective solution to improve the forest ecosystem services within this set of alternatives, which will be the one with the lowest total cost effectiveness ratio. We assume that ecosystem performance can be defined by a set of m key performance indicators, $x_j \in X = \{x_1, \dots x_n\}$. For each indicator the decision makers (based on scientific evidence) have defined some minimum quality thresholds denoted by x_i^{target}. Also, the indicators may have different measurement units. We also assume that the alternatives $a_j \in A = \{a_1, \dots a_n\}$share the same project duration and their discounted total costs? each indicator x_j denoted with c_{ij}, $\{i = 1 \dots n\}$ are known (Tabl. 1). We define the cost effectiveness ratio as:

(1) $d_{ij} = \frac{c_i}{x_j}$

For each indicator $x_j$is given a weight $w_j \geq 0$ and $\sum_{j=1}^{m} w_j = 1$

Table 1 Decision table with rows alternatives and indicators

	Indicators $(x_1, \dots, x_m)$			
	x_1 (w_1)	x_2 (w_2)	...	x_m (w_m)
a_1(e.g. Forest based action, alternative 1)	$d_{1,1}$	$d_{1,2}$	...	$d_{1,m}$
...				
a_j (e.g. Forest based action, alternative *j*)	$d_{1,j}$	$d_{2,j}$	...	$d_{j,m}$
...				
a_n(alternative *n*)	$d_{1,n}$	$d_{2,n}$	...	$d_{n,m}$

Since the measurements of the indicators can be in different units, a procedure to unify them, by transforming the values of each of the criteria into fuzzy relationships is applied.

In order to find the best alternative between alternatives presented on Tab l. 1 we will apply the transform function as defined as follows:

(2) $\mu_k(a_i, a_j) = \begin{cases} 1 & \text{when } i = j \\ 0.5 + \frac{d_{ik} - d_{jk}}{2(max\{d_{ik}\} - \min\{d_{jk}\})} & \text{when } i \neq j, \end{cases}$

where $a_i, a_j \in A$ and $k \in \{1, \dots, m\}$.

For each column of the table, the corresponding fuzzy relation R_k is obtained, i.e., for the k numbersof indicators, the corresponding matrix-like relation appears

$$(3)\ R_k = \begin{Bmatrix} \mu_k(a_1, a_1) \dots \mu_k(a_1, a_j) \dots \mu_k(a_1, a_n) \\ \mu_k(a_i, a_1) \dots \mu_k(a_i, a_j) \dots \mu_k(a_i, a_n) \\ . \\ \mu_k(a_n, a_1) \dots \mu_k(a_n, a_j) \dots \mu_k(a_n, a_n) \end{Bmatrix}, k = 1, \dots, m$$

All relations $R_k$are merged to obtain an aggregate relation R with the following matrix:

$$(4)\ R = \begin{bmatrix} 1 - \mu(a_1, a_1) \dots 1 - \mu(a_1, a_j) \dots 1 - \mu(a_1, a_n) \\ \dots \\ 1 - \mu(a_i, a_1) \dots 1 - \mu(a_i, a_j) \dots 1 - \mu(a_i, a_n) \\ \dots \\ 1 - \mu(a_n, a_1) \dots 1 - \mu(a_n, a_j) \dots 1 - \mu(a_n, a_n) \end{bmatrix}, k = 1, \dots, m$$

Each element of this matrix is calculated using the formulas for aggregating operators with weights ($w_1, \dots, w_m$). The following operators are used?, such as values of $\mu_k(a_i, a_j)$ are taken from (5).

(5) $\mu_k(a_i, a_j) = \sum_{k=1}^{m} w_k \mu_k(a_i, a_j)$,

or

(6) $\mu_k(a_i, a_j) = \prod_{k=1}^{m} [\mu_k(a_i, a_j)]^{w_k}$

Two aggregate matrices of the type *R,* are obtained.

Each of these matrices is recalculated to obtain a matrix R' as follows:

if $\mu(a_i, a_j) \geq \mu(a_j, a_{ij})$, then $\mu'(a_i, a_j) = \mu(a_i, a_j)$ and $\mu'(a_j, a_i) = 0$.

In any of the matrices obtainedthe alternative with onlywithnon-zero values is chosen as optimal.

Application of Value based Model (VBM)

In many cases it is useful to apply a modeling based on expert knowledge. VBM provides such an opportunity. The presented approach is based on stochastic programming and the Utility theory [Keeney and Raiffa 1999]. The Utility theory basically deals with the expressed subjective preferences. Possible criteria for "the meaning of best" can be an expert (decision maker -DM) utility function (Pavlov and Andreev 2013). Standard description of the utility function application LS presented by Figure (1).

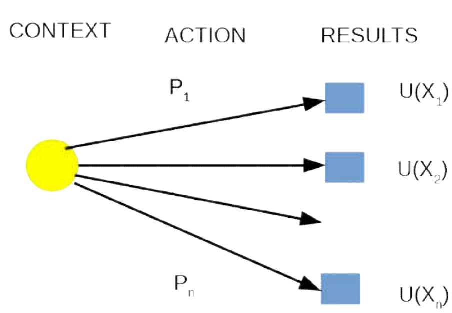

Fig 1 Utility function

There are a variety of final results that are a consequence of the experts' or DM's choice and activities. This activity is motivated by a DM (Decision maker's) objective which possibly includes economic, social, ecological or other important process characteristics. A multi attribute utility function $U(x_i)$assesses each of the final results (x_i, i=l, … ,n). The DM judgment is based on the DM choice and is measured quantitatively (discrete set of final results in this case) by the following formula (Fishbarn1970)

(7) $u(p) = \sum_i p_i u(x_i)$, p = $(p_1, \dots p_n)$, $\sum_i p_i = 1$.

Further, we will present a use case of applying VBM for forest management. The problem being considered in a dialogue with the DM or expert, defines the following main objective of investigation: to develop a value based model (VHM) for integrated assessment of economic, ecological and social forest ecosystem services, which could be applied for monitoring and ecological management of forest areas and allow the sustainable development of business and use of forest resources. Modeling of such complex system as the forest ecosystem is a difficult task, especially if one needs the functions to be regulated and subordinated to the multifaceted sustainable use. For the modeling purposes we accept three indicators (sub-objectives or factors) adequately describing the main objective of the investigation: X_1 - timber reserve: ($m^3.ha^{-1}$) as representing criteria for the assessment of economic effects or provisioning services; X_2 – species richness, (n. ha^{-1}) representing criteria for the assessment of ecological effect or regulating and supporting services and X_3 percentage of population employed in the forestry sector and representing criteria for the assessment of social effect or services. The model is developed as multy-attributes utility function with the three factors mentioned. The coefficients of function were calculated using the preferences? of ecology and environmental professionals. The expert analysis and earned structuring led to accepting the following sub-objectives and the appropriate criteria, which adequately describe the main objective and are real, physically measured quantities. We determine the domain of variation of representing criteria as follows:

- X_1- factor (provisioning services as volume of timber per hectare - economic effect) [10 - 300 nrlha'1]:
- X_2 - factor (regulating and supporting services - ecological effect) [1 - 200 number of species per hectare]:
- X_3- factor (percentage of employed meals in the forestry sector - social effect) [1 - 30 %].

Graphically the structure of the main DM's objective has the form shown in Fig. 2.

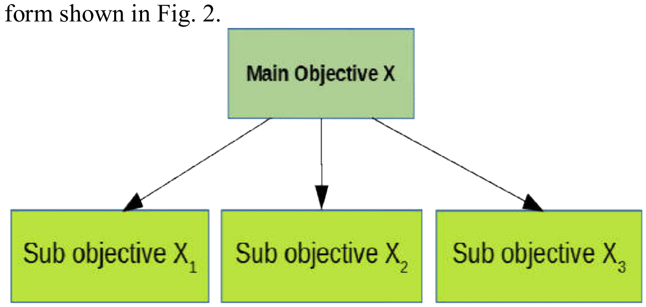

Fig 2 Main objective and three subobjectives

The preferences of DM for x_2 at different values of $x_1$and x_3 do not change, suggesting independence of x_2 from the changes of the other two factors. This means that whatever the reserves of wood are and the difference of richness of the species in the forest ecosystem, in any case, the preferences are aligned with the increasing of number of workers in the forestry sector. At low timber reserves and a poor species composition the increasing of employment in forest sector is motivated by the need of reforestation, regeneration, cultivation of existing forests, optimization of forest-related natural resources, development of alternative uses and others. At high timber reserves and rich species composition, the increasing of employment is motivated by the opportunities of multifaceted use of forests and the need of environmental management and balanced utilization of forest resources. Using the theory for decomposition of multi attribute utility applied to simpler functions given in (Keeney, 1999) we determine the following multi attribute utility structure:

(8)$u(X) = k1u(X_1, X_2^0, X_3^0) + f_2(X_1)u(X_1^0, X_2, X_3^0) + f_3(X_1)u(X_1^0, X_2^0, X_3,) +$
$+ f_{23}(X_1)u(X_1^0, X_2, X_3^0)u(X_1^0, X_2^0, X_3,)$, where $u(X_1^0, X_2^0, X_3^0) = 0$ and $u(X_1^*, X_2^*, X_3^*)$=1.

In the formula above $X^0 = (X_1^0, X_2^0, X_3^0)$ = (10, 1, 1) and $X^* = (X_1^*, X_2^*, X_3^*)$ = (300,200,30).

The functions f_2, f_3 and f_{23}have forms

$f_2(X_1) = u(X_1, X_2^*, X_3^0)$ - $k_1u(X_1, X_2^0, X_3^0)$

$f_3(X_1) = u(X_1, X_2^0, X_3^*)$ - $k_1u(X_1, X_2^0, X_3^0)$

$f_{23}(X_1) = u(X_1, X_2^*, X_3^*)$ - $k_1u(X_1, X_2^0, X_3^*)$

Each of these six functions was evaluated based on the DM's preferences. For example, the function$u(X_1, X_2^0, X_3^0)$ has the form presented on Fig. (3).

The blue see sow? line is pattern recognition of the positive or the negative DM's preferences. The solid line is evaluated Utility function polynomial approximation $u(X_1, X_2^0, X_3^0)$. Fig. 4 shows a comparison between the evaluated Utility function $u(10, X^2, X^3)$ and the evaluated Utility function $u(10, X^2, X^3)$

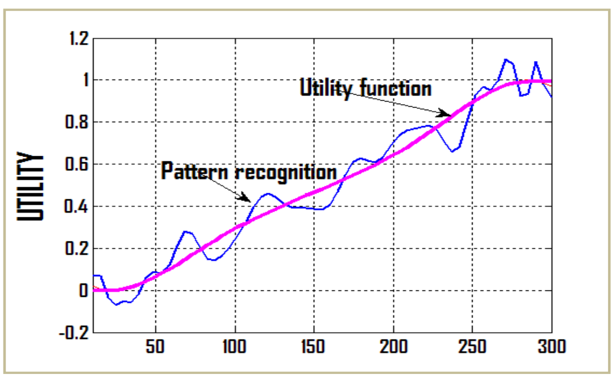

Fig 3 Graphical representation of utility function $u(X_1, X_2^0, X_3^0)$

Some results from simulations are presented on Table. 2

Table 2 Similar utility resulted from the simulations

Utility	X_1	X_2	X_3	Utility	X_1	X_2	X_3
0.0	10	50	1		70	200	7
	10	1	30		150	200	1
	70	1	1		300	50	7
01.-0.2	10	11	15	0.5-0.6	10	200	30
	10	50	7		300	200	1
	10	200	1		150	100	
	10	70	1	0.7-1.0	300	200	30
0.3-0.4	10	100	300		300	100	15
	10	20	7		150	200	15

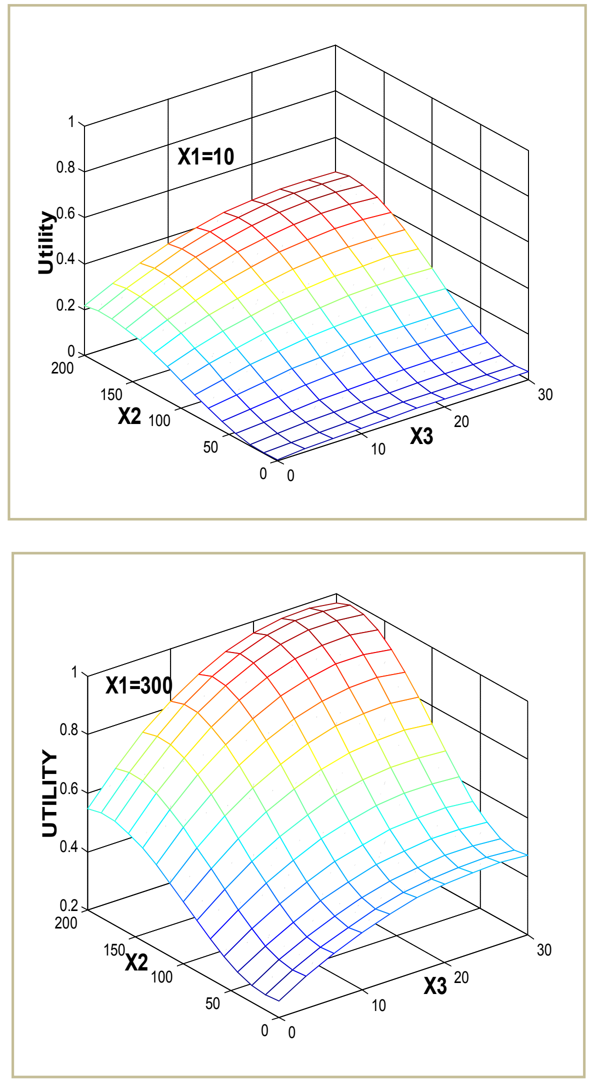

Fig 4 Comparisin between Utility functions $u(10, X^2, X^3)$ and $u(10, X^2, X^3)$

Application of Artificial Neural Networks

In the summary below, we will illustrate the ANN created by means of a specific example.In this article, a studyhas been conducted on the expected level of pollution of the Danube with the substance Ammonium Nitrogen - N-NH4. Data on the measured levels of pollution the river are 1827 observations in total and are reported at regular intervals every 24 hours.The created application generates a probabilistic model based on Estimated Time Series through the capabilities of the Artificial Neural Network.It generates a probabilistic model through training based on supplied historical data. The input data in the particular case presented is normalized, in the nterval -1 +1. The normalization takes into account the smallest and largest values in the time line.The normalzation formula is:

$$\text{RS} = \frac{(CS - \text{SMin})}{(\text{SMax} - \text{SMin})} * (\text{RawMax} - \text{RawMin}) + \text{Raw}$$

Where RS is the rescaled sampling, SMin is scaled minimum, SMax is scaled maximum, RawMax is maximum raw value, RawMin is minimum raw value and Raw is measured raw value. The normalized set of time series data is conditionally divided into two subsets - a window of past data (Lag frame) and a window of data for future period (Lead frame). The training of the Neural Network and the level of error it generats togeter with the weights submitted is reported at regular intervals.On Fig. is presented the measured values and on Fig, are presented the normalized valus.

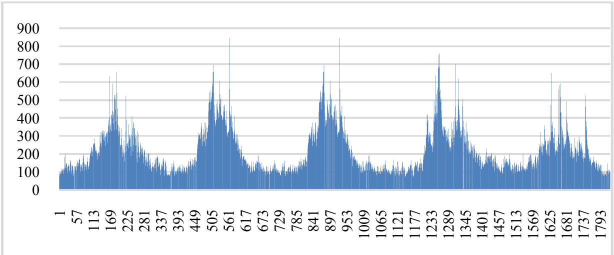

Fig 5 The measured values of Ammonium Nitrogen - N-NH4

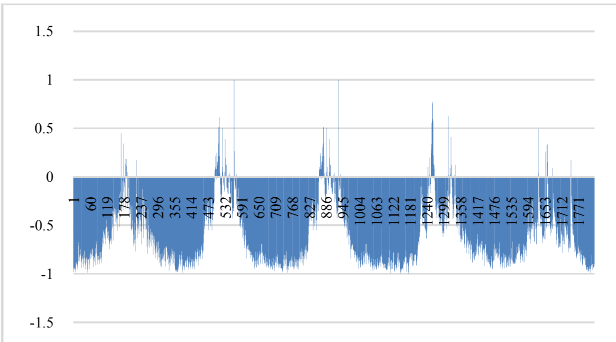

Fig 6 Graphical representation of normalized data

Figure 6 presents the learning outcomes of the Neural Network with the normalized data set submitted, and the error in the course of its training is traced. Its average value is 0.05. An array of four values is fed to the trained Neural Network(lag), which are -0.958360274, -0.943100996, -0.928876245 -0.93249709, and the neural network must generate a probability model for the next two values(lead), which ar 0.895771369 и -0.92680719. The estimate the neural network gives for these two valuesis e – 0,9557624 и -0.9557024. After recalculation the obtained values are 88.827676 и 88.804483.

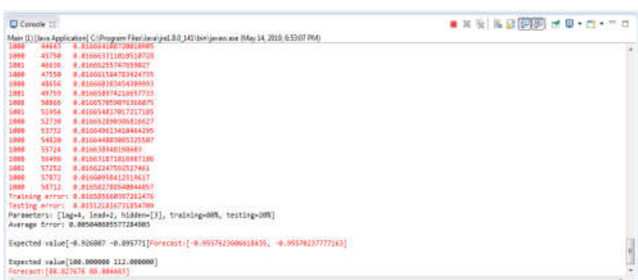

Fig7 Results obtained from network training

The three proposed methodologies are implemented as components of the author-developed ecosystem services management system presented in Figs.. 8.

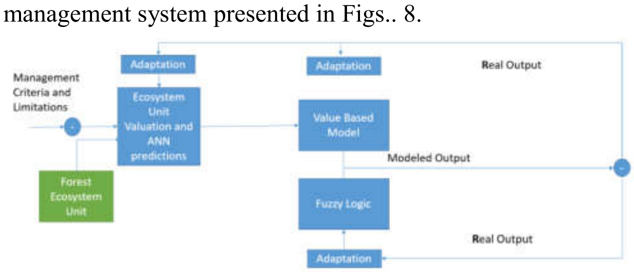

Fig 8 Schematic representation of adaptive ecosystem services management

CONCLUSION

The publication presents implementationc of three methodologies in the process of managing ecosystem services. The authors propose a cyclical process. Eachcycleconsists of two main stages – preparation phase and ecosystem service implementation phase. The activities carried out in the first stage are: evaluation of the results of the previous cycle, use of neural networks to predict the values of key indicators, simulations based on MA and VDM and decision-making. Next stage is the stage of implementation of the decisions taken. This stage, in turn, is divided into a series of iterations. At the beginning of each iteration, the feedback from the implementation of the solutions is analyzed by analyzing the changes in the ecosystem service provision. If there is a need for change in the decisions, the simulation is performed again on the basis of the new information accumulated, and then corrective decisions are made (Fig. 8). The approach proposed is innovative and unique, as it involves the consistent use of the methodologies described above, and also allows for flexible management by continuously monitoring feedback data and performing simulations to support operational and adequate decisions.

The future development of developedalgorithms will be related to their import into the high performance Apache Spark and Apache Hadoo environments. This will allow for various simulations with thousands of conditions.

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