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ECONOMIC BENEFITS OF USING DECISION SUPPORT TOOLS FOR ENVIRONMENTAL POLICY MAKERS

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SUMMARY

Decision made by using a possibilities of information and communication technologies are very crucial for the domain experts for many reasons. First, there would be minimal possibility for doubts and concerns for the decision, instead of making a decision on some potential insaights and theoretical knowledge only. Second, the economical benefits are significantly larger when we make an informed decision. And last but not least, the policy makers would have an efficient and more trustworthy source for making and proposing policy changes. In this work, I will present improved logical sieve, a quantitative tool for decision making developed for environmental policy makers and farmer advisors. This tool was made by modelling soil biodiversity and habitat, one of the most important soil functions, on a varous real-life scenarios.

KEYWORDS: *decision support, economic benefits, logical sieve, quantitative models*

EKONOMSKE KORISTI UPORABE ORODIJ ZA PODPORO PRI ODLOČANJU ZA OBLIKOVALCE OKOLJSKE POLITIKE

POVZETEK

Odločitve, ki so sprejete s pomočjo uporabe naprednih možnosti informacijsko-komunikacijskih tehnologij, so za domenske strokovnjake zelo pomembne iz več razlogov. Prvič, zaradi obstoja minimalne možnosti za dvome in pomisleke pri odločitvi, namesto da bi se odločali zgolj na podlagi morebitnih spoznanj in teoretičnega znanja. Drugič, gospodarske koristi so bistveno večje, če sprejmemo premišljeno odločitev. In ne nazadnje, oblikovalci politik bi imeli učinkovit in zaupanja vreden vir za oblikovanje in predlaganje sprememb politike. V tem delu bom predstavil izboljšano logično sito, kvantitativno orodje za odločanje, razvito za ustvarjalce okoljske politike in svetovalce kmetov. To orodje je bilo izdelano z modeliranjem biotske raznovrstnosti tal in habitata, ene najpomembnejših funkcij tal, na različnih scenarijih iz resničnega življenja.

KLJUČNE BESEDE: *podpora pri odločanju, ekonomske koristi, logično sito, kvantitativni modeli*

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INTRODUCTION

Every day, all humans have to choose between alternative actions in order to make a decision for some complex problems. Very often, they are not able to make a decision without a help of computer system. Computers help to decision-makers to make a correct and not biased decision for any complex problems. Decision- making is a process that can be defined as activity of person or computer tool which, through the use of explicit formalized models, help obtain a response to a query posed by somebody involved in decision process. In very easy decision problems that covers our decision on "daily-basis", explicit formalization is not needed. But, for more complex, real-life decision tasks it is not true. They need a formalized models because they involve more than one decision criteria, events or factors that influence final decision. Furthermore, some of the events have unknown behavior in future where decision is make under uncertainty, or the behavior can be probabilistically predicted in such cases decision is make under certain risk (Figueira et al., 2005)

We have a decision making process-where humans make a decision using computer as an accelerator or support of a decision process. They are called *decision support systems*. From the other hand, there are decision-making processes which are fundamentally different from human decision making. In this kind of processes, decision is made using computers as decision makers. Those computer decision-making processes are called *decision systems*. Here, computers make decisions according to programmed functions and procedures, which can be easily observed, analysed and modified during their operation.

Decision making consists of two main components: the set of *alternatives*, judged by the decision maker, and the *goals* to be satisfied with the choice of one alternative. There are several activities involved in decision making process: identification of the decision problem; collecting and verifying relevant information; identifying decision alternatives; anticipating the consequences of decisions; making the decision; informing concerned people and public of the decision and rationale; implementing the selected alternatives and evaluating the consequences of the decision (Bohanec, 2006)

There are a lot of computer systems developed in order to support humans in making decisions. Most of them are dealing with event responses represented quantitatively, while few of them works with qualitative criteria or event responses. In this study we are focused in quantitative decision making methods, using Improved Logical Sieve (ILS) approach, because our practical decision task is dealing with attributes which are mostly quantitative. After evaluation of alternatives, we are validating on five real-life scenarios, created by domain expert.

IMPROVED LOGICAL SIEVE (ILS) METHODOLOGY

Improved logical sieve (ILS) method is an extension of already existing sieving method used for ranking the set of alternative and choosing the most relevant one. The potential alternative is assessed by *factor* score which is an aggregation of *pertinence score, applicability* and *discrimination score,* and *technical category* (Ritz et al., 2009). The original logical sieve method presented in existing literature is quantitative feature (alternatives) ranking method. Ritz et al. (2009), developed this method in order to rank biological indicators for monitoring food and fibre production, environmental interactions, and habitats and biodiversity support soil functions on data from UK i.e., national level. Through questionnaires, this method collects relevant expert knowledge based on indicator relevancy for assessing of soil functions. At the end, based on expert decision, a set of biological indicators with the highest ranks are chosen.

Griffiths et al. (2016), used the same logical sieve method in order to choose the most relevant cost-effective and policy relevant biological indicators for monitoring the soil biodiversity function. Stone et al. (2016), also, used logical sieve method in order to rank a list of biological indicators but he extend the monitoring on a European level instead of UK level as proposed by Griffiths et al. (2016).

Improved logical sieve method is a quantitative decision making methodology where the factor scores are used for each attribute (indicator) as a weight of relevance to the basic feature that need to be assessed. Formally, we have a set of *n* highly ranked attributes $\{a_1, a_2, ..., a_n\}$. Using original logical sieve method, attributes can be ranked with assigning a factor scores (weights) $\{w_1, w_2, ..., w_n\}$ for each $a_1, a_2, ..., a_n$ accordingly. For each attributes, there are pre-defined *functions of response curves* (integration functions) $f_i(a_i)$, for all $i \in \{1,2,...,n\}$, which quantifying relationship of attribute to BF (basic feature). Then, the quantitative score for the basic feature is obtained as a weighted sum of values of functions of response curves and factor scores (weights):

$$\boldsymbol{BF} = \frac{1}{n}\sum_{i=1}^{n} w_i f(a_i).$$

Note that, improved logical sieve method (ILS) was proposed in LANDMARK project (LANDMARK, 2019) from one of the project partners (Van Leeuwen et al., 2017).

DEFINITION OF DECISION PROBLEM

The decision problem we are trying to solve is from agriculture domain. Namely, our task is to structure the knowledge collected from soil experts in order to assess the biodiversity and habitat as one of the soil functions. Collecting of knowledge is based on questionnaires, which consist a table of attributes and categories in which these attributes belong, determined in advance from general conceptual model (Schulte et al., 2014; Van Leeuwen et al., 2017).

The questionnaire was filled by soil experts and consists of numerical values for each of the attributes and weights for higher-level attributes that represents a relevance of the higher-level attributes to the biodiversity and habitat as a main soil function we want to assess. The set of attributes and their categorical scales are given in a Table 1. We have a set of 23 input attributes (22 numerical and 1 categorical) connected with each of four higher-level attributes (Van Leeuwen et al., 2019).

Table 1. Description of attributes and super-attributes for biodiversity and habitat

Soil Function	Super-attributes	Input attribute (unit)	Outcome scales
Biodiversity & Habitat	**Biology** **Nutrients** **Structure** **Hydrology**	**Earthworm community** (%) **Enchytraeid community** (%) **Microbial biomass** (%) **Bacterial biomass** (%) **Fungal biomass** (%) **Nematode community** (%) **C mineralisation rate** (g/kg/year) **Organic C/N/P/K** (%) **C:N ratio** **Clay mineralogy** (K-Kaolinite, I-Illite, S-Smectite, C-Chlorite) **CEC** (mol/kg) **Fe/Al** **Ca/Na** **pH** **Salinity** (ppm) **Texture** (%Clay) **Rooting depth** (m) **Bulk density** (g/cm^3) **Drainage class** **Soil slope** (%) **WHC** (%) **Soil temperature** (°C) **Soil frost days** (days)	**For attributes:** Most relevant High relevance Medium relevance Some relevance Low relevance No relevance ------------------------ **For Soil Function:** Low performance Medium performance High performance

MATERIALS AND METHODS

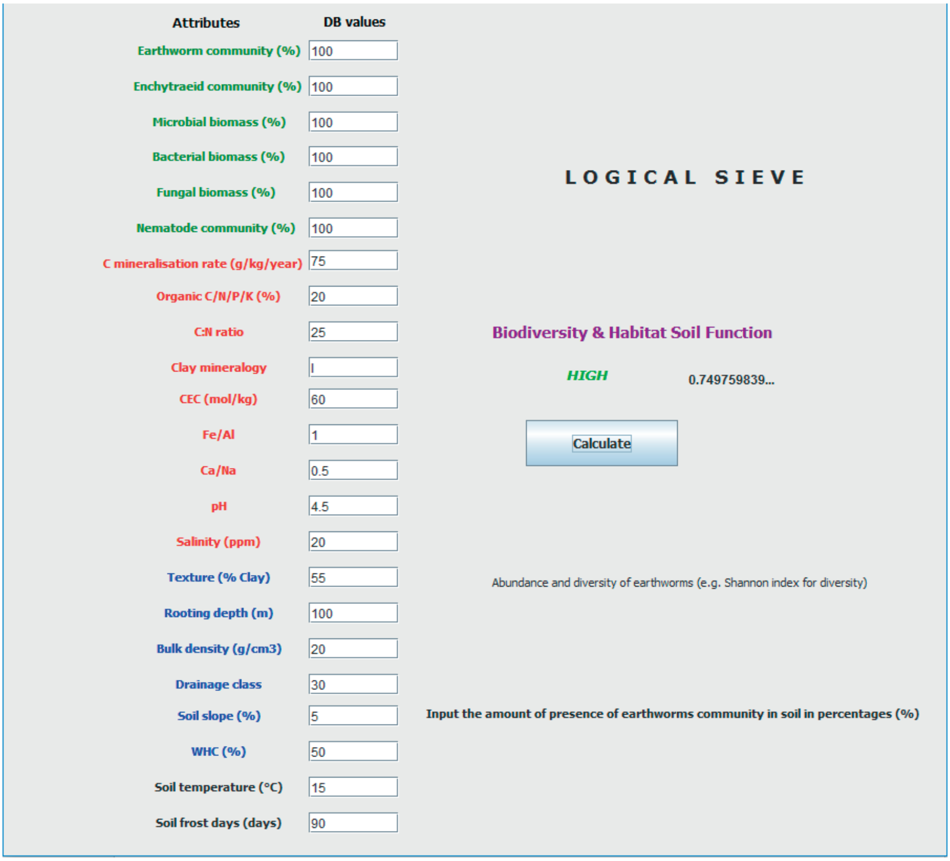
I have developed a Java Applet tool based on the quantitative decision support methodology ILP, that I am going to explain in the next subsection.

ILP JAVA APPLET

As we mentioned, improved logical sieve methodology was elaborated in LANDMARK EU Project (LANDMARK, 2019), as part of the potential decision making techniques. In order to automatize the calculations of a soil function performance with inputing a values for the relevancy of the attributes, we implement an Java Applet for this Logical Sieve method.

The screenshot of this applet is shown in Figure 2 below.

Figure 2. Logical Sieve GUI applet for quantifying Biodiversity and Habitat



User should input a numeric values for proper measured attributes according to the explanation given in a lower right part in the Applet. The description of the attribute and the range of values for inputting are shown on positioning mouse cursor to the name of the attribute.

At the end, on click *Calculate* button, the assessed qualitative and quantitative value for Biodiversity and Habitat soil function is shown under the name "Biodiversity & Habitat Soil Function". To map the quantitative value to qualitative we are using the following expert's defined thresholds as *HIGH* in the interval [0.67,1], *MEDIUM* in the interval [0.33,0.67) and *LOW* in the interval [0,0,33).

Next, we present the details of improved logical sieve methodology.

Via questionnaires filled by domain experts, the knowledge was collected about attribute relevance to biodiversity and habitat and factor scores were determined, using the aggregation formula, which consider relevancy, sensitivity and specified weights of the higher-level attributes. The values of the attributes represent their influence on the higher-level attributes. On Table 2 are shown the attributes descending ordered by factor score *wi*.

Table 2. Ordered list of factor scores wi of attribute for biodiversity & habitat

	Factor score (wi)
Earthworm community	1.294
Bacterial community	1.282
Microbial biomass	1.261
Organic C/N/P/K	1.202
Microarthropod community	1.187
Fungal community	1.182
pH	1.163
Texture	1.160
Rooting depth	1.100
Nematode community	1.095
Enchytraeid community	1.019
Clay mineralogy	1.011
Bulk density	1.002
C mineralisation rate	0.969
C:N ratio	0.956
Drainage class	0.928
Soil temperature	0.901
WHC	0.822
Salinity	0.812
CEC	0.806
Soil slope	0.764
Soil frost days	0.733
Fe/Al	0.729
Ca/Na	0.623

The integration function or response curves $f(a_i)$ for each of the attributes are defined using the domain experts knowledge sieved through various different workshops during the Landmark project development (LANDMARK, 2019; Van Leeuwen et al., 2019). The list of all functions of response curves is given in **Figure 3** below.

Finally, numerical assessment for biodiversity and habitat soil function is obtained using the equation proposed by Rudgers et al. (2016):

$$\log(\mathcal{SF}) = -\frac{\sum_{i=1}^{N}\left(w_i \cdot \left|\log(f(a_i))\right|\right)}{N}$$

where w_i is a (corrected) factor score obtained from logical sieve, $f(a_i)$ are the functions of response curves quantifying relationship of attribute to SF (soil function). We use the logarithms into the equation because we want to map the output value in [0,1] interval.

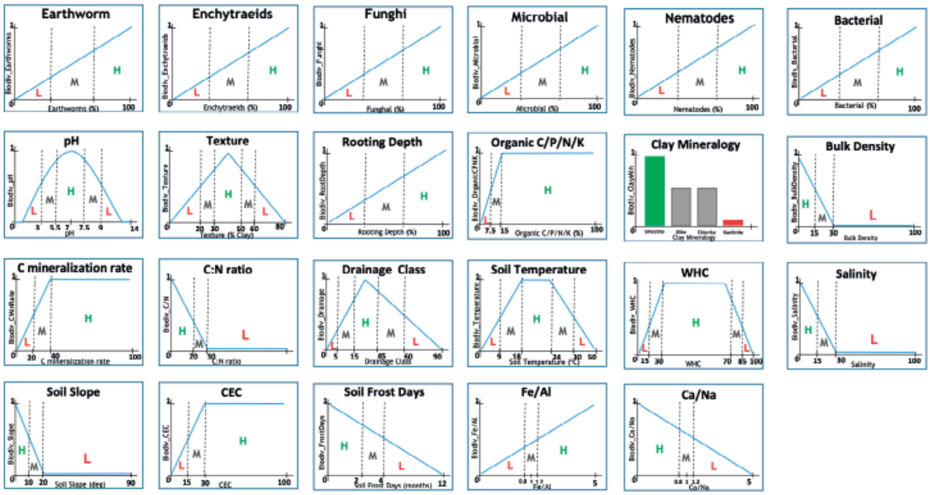


Figure 3. *Response curves (utility functions) that quantifying the relationship of attributes to the biodiversity and habitat soil function. For each input attribute iven is a range of values which quantify soil function with qualitative values (**L** - low; **M** - medium; **H** – high)*

Table 3. Obtained results for five different Scenarios obtained from ILS model. Green cells represent the HIGH PERFORMANCE, white represent MEDIUM PERFORMANCE and red cells represent LOW PERFORMANCE values taken from response curves in Figure 3.

	Scenario 1	Scenario 2	Scenario 4	Pasture	Forest
Earthworm community	100	40	100	50	100
Bacterial biomass	50	40	100	50	100
Microbial biomass	50	5	100	50	100
Organic C/N/P/K	5	10	10	10	20
Fungal biomass	50	5	100	50	100
pH	7	7	4.5	4.5	4.5
Texture	5	5	55	55	55
Rooting depth	50	40	100	50	100
Nematode community	100	40	100	50	100
Enchytraeid community	100	40	100	50	100
Clay mineralogy	K	I	I	I	I
Bulk density	20	25	20	20	20
C mineralisation rate	75	30	30	30	75
C:N ratio	75	25	25	25	25
Drainage class	30	6	50	50	30
Soil temperature	15	2	15	2	15
WHC	50	20	20	20	50
Salinity	75	75	20	20	20
CEC	70	30	30	30	60
Soil slope	5	15	15	5	5

Soil frost days	130	180	180	150	90
Fe/Al	1.5	1.5	1	0.5	1
Ca/Na	0.5	1.5	1	1	0.5
ILS	**MEDIUM**	**LOW**	**MEDIUM**	**MEDIUM**	**HIGH**
Numerical values from ILS	0.61	0.319	0.65	0.478	0.75

RESULTS

In order to evaluate the ILP model, we create five different real-life scenarios, which represent the most of the possible situations. The scenarios and obtained results from both decision support methods are shown in a **Table 3** above. Due to the sensitivity of the data and knowledge practices, we encrypt the names of the Scenarios and make them as general as possible.

It is very important to notice that numerical values obtained from improved logical sieve in Scenarios 1 and 3 (marked as yellow) with the values 0.61 and 0.65, accordingly are very close to the pre-defined threshold 0.67. Because of arbitrariness in a thresholds determination, we can say that the difference is not a significant.

In Scenario 5 (Forest type of field) we could see that the higher values of the first set of attributes i.e., biological attributes are contributing the most to the final assessment of soil biodiversity and habitat. Latter confirms current theoretical findings. Following the factor scores given in the Table 2, from the results in Scenario 1 and Scenario 2, we can note that, any level-up change (low to medium or medium to high) or level-down change (high to medium or medium to low) in highly ranked attributes (communities, biomasses and Organic C/N/P/K) is reflecting to the changing in soil function value in the top node. Finally, ILP model gives the expected decisions based on a values obtained from domain expert opinions.

CONCLUSION

In this work, I have presented one programmed tool based on experts rules and predefined thresholds form the domain knowledge. The main and crucial advantage of improved logical sieve is the numerical type of attribute values. This is very important in case of validation with real data, because user can directly input the measured value for proper attribute and then, using the ranges of values defined by expert, can be easily converted to categorical. However, there is a disadvantage of Improved logical sieve tool, because it is not visualizable, compare to the other existing decision support tools.

For the further work, we could make a comparative analysis with another well-known decision support tool, called DEXi (Bohanec and Rajkovič, 1990). Then, we could validate both models on a real data about soil biodiversity and habitat as soon as data will be available. Another potential idea for further work is improvement of logical sieve method in a form of framework which will work on multiple basic features i.e., more than one soil function using the same or additional attributes (alternatives). Last but now least, it could be very beneficial if we could incorporate an financial data for the farmer management practices and confirm the economical benefits by using of such a tool instead of decision made by only domain knowledge and farmer's insaights.

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