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ПІДХІД БАГАТОКРИТЕРІАЛЬНОЇ ОПТИМІЗАЦІЇ ДО МЕНЕДЖМЕНТУ ЛІСОВОГО ГОСПОДАРСТВА З УРАХУВАННЯМ БАГАТОЦІЛЬОВОГО ВИКОРИСТАННЯ

Враховуючи, що менеджмент лісового господарства дуже важливий для забезпечення рівноваги в економічних, екологічних і соціальних цілей, ми представляємо багатокритеріальну і багатовимірну модель підтримки прийняття рішень. Вона дає змогу визначити оптимальне управлінське рішення з урахуванням вимог сталого розвитку і різноманітного використання лісів. Запропонована модель підтримки прийняття рішень розглядає процес менеджменту лісового господарства з урахуванням стану, рішень, цільових функцій та зважених вартостей. Оскільки стан лісу описують з допомогою суб'єктивних і недостовірних змінних, ми використали апарат нечіткої логіки. Відтак лінійна функція корисності, багатовимірний аналіз та аналіз ієрархічних процесів використано для оцінки конфліктуючих цілей землевласниками, експертами і громадою, а також для схвалення оптимального рішення, тобто рішення, яке має найвищу компромісну оцінку.

Ключові слова: менеджмент лісового господарства, багатокритеріальна і багатовимірна модель підтримки прийняття рішень, багатокритеріальна і багатовимірна модель, методи нечіткої логіки.

A Multi-criteria optimization approach to forest management regarding its multiple-use²

Taking into account that in forest management it is indispensable to create an equilibrium of economic, ecological and social objectives, we present a multi-criteria and multivariate decision support model. It enables the determination of the optimal management decision based on a concept of sustainable and multiple uses of forests. The presented decision support model considers the forest management process in terms of states, decisions, objective functions, and their weighted values. Because the state of the forest is also described with subjective and uncertain variables we use for these uncertainties and imprecision fuzzy methods. Further, the linear utility function, multivariate analysis and analytic hierarchy process are used to evaluate the conflicting objectives by landowners, experts and public, and finally to select the optimal decision, i.e. the one with the highest compromise value.

Keywords: forest management, multiple-use of forests, decision support model, multi-criteria and multivariate methods, fuzzy methods.

1. Introduction

General awareness of natural resource limitations is growing. Ecological crisis and social demands for maintaining the natural environment play an active role in many public discussions. These issues have, along with the existing economic criteria, become a key part of the modern concept of management of the environment. This is also true of forestry and forest management, what is in the last decades clearly expressed by several acts (in USA, for example, in: 1960 Multiple Use and Sustained Yield Act, 1969 Environmental Policy Act, 1975 National Forest Management Act – see Driver, 1990, and Rauscher, 1999), agendas (for example: UNCED, Agenda 21, Conservation of Biological Diversity, Rio de Janeiro, 1992, WRI, IUCN, UNEP, Global Biodiversity Strategy, Baltimore, 1992, the 5th Environmental Action Program "Towards Sustainability" accepted by European Parliament in 1998, followed by Agenda 2000 – see Brown, 1993, and Biodiversity Conservation Strategy of Slovenia, 2002), and is applied by several authors dealing with forestry problems (for example: Sleavin and Camenson, 1994, Lippke et al., 1996, Brumelle et al., 1998, Rauscher, 1999, Schmoldt et al., 2001, Kangas and Kangas, 2002, etc.). Forest management, being an important branch of the economy and environment, is generally defined by the state Forest Act (in Slovenia, for example, by Republic of Slovenia Forest Act, 1995, and by Biodiversity Conservation Strategy of Slovenia, 2002) and includes the protection, silviculture, exploitation and use of forests, as well as ensuring the multipurpose management of forests, since forests have been designated a natural resource. The state or the owner of a forest should maintain and use the forest, while society as a whole benefits from the amenity value of that forest. Therefore, we deduce that the forest management problem consists of decisions on how to schedule forest activities for an existing forestland. These decisions, which are assumed to be undertaken in a forest system in order to support the development of a forest process, should maximize the expected profit for the landowner, and guarantee the present and future needs of the society as a whole, while taking into

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consideration ecological and social objectives, i.e., the decision should maximize the utility of the owner and society.

Consequently, in forest management process, the decision-maker is challenged with a large-scale and complex decision problem which is a multi-objective and stochastic problem. This problem has during the last decades precipitated the development of various interdisciplinary decision support models (DSM) to aid human ability to understand and evaluate forest management situations and scenarios.

DSM is a concept in which a computer system is placed at the disposal of the decision maker, who uses data and procedures to formulate a problem, and to evaluate decisions.

The decision making process searches for the "optimal" decision, and thus includes formulating the problem, designing activities (alternatives, decisions), setting the goals, evaluating the consequences for each decision, and finally ranking the consequences according to the preferences, i.e., finding the alternative that maximises the utility. This approach is usually developed by the use of operations research or system analysis methods. The decision making process is above all concerned with how to choose from a set of alternatives, therefore it usually falls short in framing the problem, developing the alternatives, setting the goals and implementing the decisions.

Forest management process with multiple objectives, and often with multiple stakeholders with conflicting interests points towards optimisation methods, and in the last decades indicates the possibilities to utilise the multiple criteria decision support (MCDS) models. Taking into account the problem of forest management and having in mind the fact that it is indispensable to create an equilibrium of economic, ecological and social objectives, we present a multiple-criteria and multivariate decision support model which enables the determination of the optimal sequence of decisions based on a concept of sustainable and multiple-use of forests. In the presentation, the forest management process is defined in terms states, decisions, objective functions, and their weighted values. Because the state of the forest is also described with subjective and uncertain variables we use for these uncertainties and imprecision fuzzy methods. Further, utility theory (Keeney and Raiffa, 1976), multivariate analysis are used to evaluate the conflicting objective functions by landowners, experts and public. After the assessment of management decisions is completed, we elicit the joint utility, i.e., an acceptable trade-off between conflicting objective functions, using the weighted values of decisions defined through analytic hierarchy process. To illustrate the problem and methods of the system we present some computational experiences from a case study (management of a forest in south-west part of Slovenia).

1.1. A brief review of DSM for optimal forest management

Models are essential for nearly all forestry activities (Buongiorno and Gilles, 1987) and few decisions are made without referring to them. Most abstract models are mathematical models in which reality is described in terms of the algebraic relationships between them.

Forest management models involve economic, biological, environmental, social, and sometimes even legal variables. These variables are interrelated and can

thus be defined in terms of each other. Methods used to solve such models are developed within the discipline of operations research, of management science, and of system analysis. Working groups all over the world have been studying the applications of these methods to the field of forestry. Therefore, computer based models are not new in the field of forestry. Since the late 1970's we have witnessed a growing concern for the ability of models to satisfy the needs of planners, forestland managers and their clients. Forest management models can be classified according to the considered unit or level, deterministic or stochastic properties, and the algorithm used (linear programming, dynamic programming, multi-criteria decision making, etc.). Earlier works in the field of forest management planning stressed the application of linear programming models, such as FORPLAN, to forest management problems (Kent et al., 1985). One commonly-stated shortcoming of FORPLAN is that it is a deterministic model. Thus, some papers examine how the forest planner should understand model outputs in view of uncertainties (Hool, 1966, Kao, 1982, Gunn, 1996, Kouba, 2002).

Nonlinear programming methods, such as discrete-time and discrete-state version of deterministic dynamic programming, were applied to the optimal forest management problems by Brodie et al. (1987), Zadnik Stirn (1990), Hof (1993), Joebstl (1997). The multiple-use forest management was expressed by goal programming (Mendoza, 1986), and later by other multi-objective methods (Gong, 1992, Zadnik Stirn, 1993). Much attention has been focused on the incorporation of biodiversity into multi-objective forest-management models (Loehle et al., 2002). Indicators and public's values for sustainable forest management were studied by Prabhu et al. (1999) and Shields et al. (2002). Researchers at the Oregon State University developed a Scheduling and Network Analysis Program (SNAP) (Sessions, J. and B., 1994). The same year, researchers at the US Forest Service developed IMPLAN (Impact Analysis for Planning) which is used in US National Forests to create regional economic models. A pioneering effort to estimate the costs of sequestering carbon was made by a dynamic, nonlinear programming model of the forest, assigned as Forest and Agricultural Sector Optimization Model (FASOM) (Adams et al., 1994). Another complex, user-friendly decision support system in forestry is SPECTRUM (Sleavin, 1996).

Above all, we have to highlight that multiple criteria methods, combined with fuzzy and interactive procedures, and multivariate analysis are being developed also to predict the effects of different forest management policies on the ecological, economic and social status quo. Further, we can expose that the gap between the problem of economic, ecological and social management of the forest, and the results of the developed ecosystem management decision support systems still exists. Finally, we can persuade that optimization models can provide a set of policies which results in considerably improved decision making in sustainable forest management. All these three facts have encouraged us to generate a DSM which supports the optimization of a forest process. This attempt is presented in this paper.

2. Methods and theoretical approach to the presented DSM

The developed DSM simulates forest management decisions while providing information about the public acceptance of various types of land management

options designed by forest managers. In the model the forest management process is defined in terms of states, decisions and multiple objectives.

2.1. State variables

The state of a given forest-system is described in terms of properties (components) of the elements which comprise the forest system. These are represented by variables (parameters) $s_1, s_2, \dots, s_p$, as area of forest land, number of plant species, number of animal species, the level of conservation of biodiversity, amount of forest products, labour force, machinery, financial resources, ecological conditions, recreational possibilities, etc. Some parameters cannot be expressed precisely since the forest decision support system deals not only with parameters defined by numerical variables but also with subjective assessments and value judgments, as for example recreational possibilities, and ecological conditions. Thus, fuzzy logic is used for descriptive (linguistic) parameters (Zimmermann, 1987), i.e., a fuzzy set and its membership function are derived for each linguistic parameter. The limit values for each individual linguistic parameter are defined by means of certain rules – as "acceptable" values.

The fuzzy and non-fuzzy parameters which define the possible state of the forest system form a state vector $\underline{x}(j) = x(s_1, s_2, \dots, s_p) \in X$, where X is the set of all possible state vectors. We suppose that there is a finite number of such vectors ($j=1, 2, \dots, J$). Thus, in practice, the set X is a finite and discrete set of state vectors $\underline{x}(j)$.

2.2. Decision variables

The decision maker can influence the existing forest-system, described by the state vector $\underline{x}(j) = x(s_1, s_2, \dots, s_p) \in X$, by invoking management decisions, expressed by decision variables $d(m, \underline{x}(j))$. The decisions $d(m, \underline{x}(j))$ are determined on the base of technical possibilities, investment measures (there exist investment levels brought about by stakeholders with different interests, and on the base of silvicultural measures, as for example: no activity at all (the forest develops in accordance with laws of nature), conversion (the existing tree specimen is exchanged with a new one), thinning and stand regeneration which are undertaken at different intensity. The set of feasible decisions is further constrained by area limitations, budget constraints limiting total annual expenditures and investments (operational profit, savings, bank loan, timber sales, etc.), available machinery and labour hours, environmental constraints, the use of production means, etc. Thus, each state vector $\underline{x}(j)$ is associated with a finite discrete set of decisions $D(\underline{x}(j))$; $d(m, \underline{x}(j)) \in D(\underline{x}(j))$, $m=1, 2, \dots, M$. The decisions are mutually exclusive for any given state $\underline{x}(j)$.

The theoretical and empirical issues dealing with the question of decision making simply assume the decision variables as given, or generate the decisions for a well known and defined problem in a marginal way. Therefore, the identification and formulation of the decision variables is a problem which also has to be studied carefully. One of the novelties and contributions to the improved identification and formulation of forest management decisions is given here by the framework for generating the decisions (Zadnik Stirn, 2002).

2.3. Objective functions

The objective function defines the performance criterion and is the function that is then optimized. It reflects managerial objectives and links state and decision

variables. It is associated with state $x(j)$ and decision $d(m, x(j))$ and is a vector function $Z(\underline{x}(j), d(m, x(j)))$ with components $z(k, x(j), d(m, x(j)))$. $k=1,2,\dots, K$, because we assume that in practice K objective functions, such as net revenue from production, water quality, protection of wildlife, recreational opportunities, etc., are taken into account. Quantifiable and intangible costs and benefits of a given decision have to be determined in order to assess objectives.

2.3.1. Assessment of objective functions by utility functions

The values (preferences) for objective functions $z(k, x(j), d(m, x(j)))$ from the managers', owner's and investors' (decision maker's) point of view are required. Multi-attribute utility theory (MAUT) (Keeney and Raiffa, 1976) can help the decision maker to determine these values. Using MAUT it is assumed that the objective functions $z(k, x(j), d(m, x(j)))$ for $k=1,2,\dots, K$ are determined by attributes $a_k(\underline{x}(j), d(m, x(j)))$, each having a finite number of possible values called levels. Let $a_{k,i}(\underline{x}(j), d(m, x(j)))$ be the i -th level ($i=1,2,\dots, I$) of the k -th attribute ($k=1,2,\dots, K$) associated with the state $x(j)$ and decision $d(m, x(j))$. The vector objective function $Z(\underline{x}(j), d(m, x(j)))$, consisting of components $z(k, x(j), d(m, x(j)))$, $k=1,2,\dots, K$, is expressed as the decision maker's multi-attribute utility function $v(a_{1,i}, \dots, a_{k,i}, \dots, a_{K,i})$. In an MAUT approach, the marginal utility functions $v_k(a_{k,i}(\underline{x}(j), d(m, x(j))))$, $k=1,2,\dots, K$, are first established and then the utility function $v(a_{1,i}, \dots, a_{k,i}, \dots, a_{K,i})$ is introduced as (Alho et al., 2002):

$v(a_{1,i}, \dots, a_{k,i}, \dots, a_{K,i}) = v(v_1(a_{1,i}(\underline{x}(j), d(m, x(j))))), \dots, v_k(a_{k,i}(\underline{x}(j), d(m, x(j))))), \dots, v_K(a_{K,i}(\underline{x}(j), d(m, x(j))))$. Further, many approaches assume that the overall utility function is a weighted linear function of the marginal utility functions (Winston, 1994), i.e.,

$$v(a_{1,i}, \dots, a_{k,i}, \dots, a_{K,i}) = \sum_{k=1}^K w_k v_k(a_{k,i}(\underline{x}(j), d(m, x(j)))) \quad (1)$$

where the weight w_k presents the relative importance of objective k . In the standard version, the weights w_k are estimated applying pairwise comparisons carried out by decision makers. The relative importance of the objectives can be computed also using the analytic hierarchy process (AHP) (Saaty, 1994). There are several ways to assess the marginal utility function $v_k(a_{k,i}(\underline{x}(j), d(m, x(j))))$ in (2). If the attribute $a_{k,i}$ is a numerical variable (known with certainty), and the decision maker is risk neutral, the marginal utility function for a single attribute is linear. In this case, the function $v(a_{k,i})$ is given as (Winston, 1994):

$$v_k(a_{k,i}) = (a_{k,i} - a_{k,i, \text{worst}}) / (a_{k,i, \text{best}} - a_{k,i, \text{worst}}) \quad (2)$$

where $v_k(a_{k,i} = a_{k,i, \text{worst}}) = 0$ and $v_k(a_{k,i, \text{best}} = a_{k,i}) = 1$.

2.3.2. Public preferences assessed by multivariate procedures

Ideally, the public, i.e., various representative groups of consumers who benefit from the amenity value of the forest-system, should be included in the decision-making process. Thus, decisions must be made public. Public, representatives of consumers, or experts, assigned as respondents, express their opinion on decisions, i.e., make their own choices by conducting the survey, which we finally analyse using multivariate methods. The procedure to be followed for the evaluation of the decisions by public/residents consists of formulation of the indicators,

construction of the questionnaire in which the respondents are asked about their preferences towards the selected decisions (Zadnik Stirn, 2004), identification of the respondents, performing the interviews, and analysing the questionnaires through factor analysis and post hoc procedure (Hair et al., 1998). The objective of factor analysis is to find a way of condensing the information contained in a number of original variables (questionnaire responses) into a smaller set of variates (factors) with a minimum loss of information. The suggested procedure comprises: the specification of a number of factors (eigenvalues criterion and scree test criterion are used), interpreting the role each variable plays in defining each factor according to the decisions, calculating the means of factors which represent the evaluation of decisions by the selected interviewers; calculating the differences between the groups (decisions) and the means of groups by post hoc procedure.

2.4. Determination of relative importance (weights) of objectives

Finally, knowing the effects (normalized values) of each decision on both, owners/experts, assigned as v_{utility} , and public/residents sides, assigned as $v_{\text{f+ph}}$, the analyst determines the best compromise decision as a weighted sum of both values for each decision, i.e., the overall result (v_{or}):

$$v_{\text{or}} = w_1 v_{\text{utility}} + w_2 v_{\text{f+ph}} \quad (3)$$

The weights w_1 and w_2 are determined by AHP (Analytic Hierarchy Process) method (Winston, 1994), so that the distinctive experts are asked to reveal the pairwise comparison on the 1 to 9 Saaty's scale comparing the importance of experts/owners and public/residents for the decision making regarding the investment and management of the forest. The value 1 means that two objectives are of equal importance, 3 means that judgments slightly favor one objective over another, ..., 9 means that favouring one objective over another is of the highest possible order of affirmation, 2, 4, 6 and 8 are intermediate values, while the reciprocals of these values tell that if objective k has one of reasonable assumptions of the above non-zero numbers assigned to it when compared with objective j , then j has the reciprocal value when compared with k (Saaty, 1994). The pairwise comparison data are gathered in comparison matrix A which is a square, positive and reciprocal matrix. The vector of weights $w=(w_1, w_2)$ is calculated with multiple squaring of matrix A to the satisfactory exponent, i.e., $A, A^2, (A^2)^2$, etc. Then, the lines are summed up and normalized.

3. CASE study

Some fundamentals of the elements of the presented DSM are illustrated on the management problem of the forest Panovec which is for the sake of simplicity and with the aim to serve for illustration presented and treated in a restricted way.

3.1. The forest Panovec and its current (existing) state vector

The forest Panovec lies in the immediate vicinity of Nova Gorica, Slovenia and covers a total area of 384 ha (forest, meadows, trails), of which 364 ha are forests. An area of 19 ha and is a forest under full protection. Oak, pine, ash and beech are the main tree species. The compositional variety of species is very large (102 tree species, 869 fungi species, 33 bird species, 150 butterfly species, 7 game species, etc.), (Papež, 2001). Panovec is state owned. In 1981, the Society of Fo-

restry Engineers and Technicians of Republic Slovenia and the Forest enterprise SGG Tolmin opened the Panovec to the general public with a forest learning trail (access is free). The aim of the trail is to get more visitors (young and adult) in the area in order to educate them about the forest in many ways. The trail is also used for recreation (walking, running,...). All these properties of the Panovec forest are employed to express the current state of the forest, the state vector $x(j=1) = x(s_1, \dots, s_p)$. Most of the parameters (components) can be presented by the numerical values, while there are some of them which are only subjective judgments. They need to be defined by means of fuzzy logic. One of such, is the recreational level. Let us show how the membership functions for such parameters are produced, on the imprecise feature concerning recreational use level. If the ideal value of recreational use level x is specified as 2.5 recreation visitor-days in a year, and also the values from the interval $[1.5, 3.5]$ may be acceptable, and a triangular fuzzy set membership function $\mu(x)$ is developed (Figure 1), $\mu(x)$ is as follows:

$$\mu(x) = \begin{cases} 0 & \text{for } 1.5 > x > 3.5 \\ x-1.5 & \text{for } 1.5 \leq x \leq 2.5 \\ -x+3.5 & \text{for } 2.5 < x \leq 3.5 \end{cases} \quad (4)$$

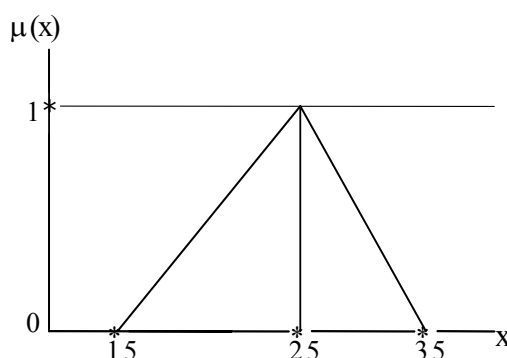


Figure 1: Membership function of recreational use level

3.3. The possible decisions undertaken in forest Panovec

The decisions of the management process in forest Panovec was determined through an intensive research of the forest and environmental experts from Nova Gorica. The basis for their expertise were the demands for a sustainable and environment friendly forest which fulfills the economic requirements of the owner and the recreational/educational desires of the public/visitors. In the existing state $x(j=1)$, the forest-learning trail is supposed to be under renovation, some new recreational and educational areas will be created, a new guide to the forest learning trail and a handy leaflet will be issued with the aim of inviting more visitors. Additionally, an evaluation of the space will be undertaken in terms of defining limits on recreational and other management activities. Different plans, evaluations, financial, ecological and social studies were examined, and a list of feasible tasks (targets, problems) which should be carried out in Panovec, was generated in the serious expertise with the decision makers in Nova Gorica. By matching the tasks, the location, level of operation, effects on environment, and financial possibilities were considered. The final list of tasks included 35 tasks. Further, there were 15 questions formulated for 35 tasks. The results of the questionnaires for all 35 tasks obtained in the interview with 9 interviewers (representatives of institutions

important for management of Panovec) are gathered in Zadnik Stirn (2002). The results were then analyzed using the cluster analysis within the SPSS program (Norusis, 2002). The most suitable number of groups (clusters) of all 35 tasks was defined by Ward criterion function, and three clusters were considered as reasonable. In such a way, three decisions were formulated. The tasks of the first decision (cluster), assigned as d_1 may be interpreted as economically oriented because the tasks comprising the first decision sustain the economic development of Panovec. The tasks composing the second decision, d_2 , are assigned as ecologically oriented because they maintain the environmental sustainability of Panovec, above all the biodiversity. The tasks of the third decision, d_3 , are educationally oriented as they support the issues developed with aim to educate the visitors about the forest in many ways.

3.4. Assessment of the forest Panovec objective functions by utility functions

In the treated example only economic objective functions $z(k, x(j), d(m, x(j)))$ of the forest Panovec were considered by MAUT procedure. If we assume that for certain economic objective functions $z(k, x(j), d(m, x(j)))$ of the forest Panovec there exist two indicators (attributes), let us say net income from cut wood, assigned as a_1 , and net revenue from non-wood forest products, assigned as a_2 , the utility function $v_k(a_k)$, ($k=1,2$), for the state $x(j=1)$ and decisions d_m , ($m=1,2,3$) is calculated according to equations (1) and (2), (Table 1, Table 2 – the second row); where the both weights in (1) were taken as equal ($w_1=w_2=0.5$). In Table 2 also the normalized values are given. The revealed utility values (second row of Table 2) show that decisions d_2 and d_3 are of equal importance, while decision d_1 is less important to the decision maker who used MAUT procedure to assess the decisions.

Table 1. Utility functions for two objective functions (attributes) and three decisions according to equation (2)

Atributte	d1	d2	d3	$a_{i, \text{worst}}$	$a_{i, \text{best}}$	$v_k(a_k, i)$	Weight
a_{1i}	20	50	10	10	50	$(a_{1i} - 10)/40$	0.5
a_{2i}	200	50	450	50	450	$(a_{2i} - 50)/400$	0.5

Table 2. The weighted joint values of an overall evaluation of decisions

Value/Decision	d1	d2	d3	Weight
Utility (v_{utility})	0.31 (0.24)*	0.5 (0.38)	0.5 (0.38)	0.56
Factor + post hoc (v_{f+ph})	3.23 (0.324)	3.42 (0.343)	3.32 (0.333)	0.44
Overall result (v_{or})	0.2770	0.3637	0.3593	

* in brackets are normalized values

3.5. Assessment of the forest Panovec objective functions by multivariate analysis

The decision maker made public the three selected decisions (d_1 , d_2 and d_3) so that residents, visitors, different NGO's, etc., who benefit from visiting Panovec, could be included in the decision making process. In our case, public assessed the chosen decisions undertaken at state $x(j=1)$. According to decisions d_1 , d_2 , d_3 and 20 questions (variables) 48 interviews with public were performed. The questionnaire with 20 questions and results of the accurately conducted surveys with 48 re-

sidents/visitors are given in Zadnik Stirn (2004). Following the scree analysis we accomplished the factor analysis with 3 factors, and concluded that factor 1 loads 9 questions from the questionnaire, factor 2 loads 6 questions, while factor 3 loads 5 questions. Because of the fact that the 9 questions explained by factor 1 significantly demonstrate the decision d_1 of Panovec, the 6 questions enlightened by factor 2 are closely connected to decision d_3 , and the last 5 questions justified by factor 3 give details about the decision d_2 , we calculated the average values from factor scores for each of the decision. Further, we conducted the post hoc procedure which produced mean values for decisions regarding the differences between decisions. Table 2 (third row) shows the mean values v_{f+ph} , obtained by factor analysis and post hoc procedure, and tells that d_2 reaches the highest average value (3.42), the second average value is reached by d_3 (3.32), and the lowest by d_1 (3.23). The results of factors analysis and post hoc with the normalized average values for all three decisions are given in the third row in brackets.

3.6. Weights for the relative importance of the selected procedure determined by AHP

Finally, using formula (3), we have calculated the joint values of an overall objective function, i.e., for the decisions d_1 , d_2 and d_3 , by taking into account the values obtained as utility function's values $v_{utility}$, and the values obtained from factor analysis/post hoc procedure v_{f+ph} , multiplied by weights $w_1=0.56$, and $w_2=0.44$ obtained through AHP method (Zadnik Stirn, 2004). The overall results v_{or} (fourth row in Table 2) show that the decision d_2 is the most important (with 0.3637), d_3 is on the second place (with 0.3593), while d_1 is the least important (with 0.2770) to the experts/owners and public/residents who evaluated the decisions according to their preferences.

4. Conclusion

Ecology, environmental planning, politics, economics and social questions are some of the issues involved in forest management planning. Thus, the solution to the multiple-use forest management problem involves the integration and coordination of multiple decision makers and can not be obtained by the sole use of any one operations research method. The combination of multi-objective techniques, captured in a DSM, that can also accommodate interactions with the stakeholders was presented. It may provide credible solutions and facilitate the acceptance and implementation of the forest management decisions. Further, the decision makers must generate forest land management decisions and make them known to the public. The public can then make choices and define their own best land management scenario. Thus, the end users of a presented decision support system might be forest institutions or enterprises in charge of public woodland management, rural development institutions, private owners of woodlands, and mixed farms using their land for both forestry and agriculture.

With the emphasis placed on public input it is clear that this area deserves increased attention. One real difficulty of generating and analyzing the forest management decisions is that there is considerable uncertainty about the impact values. These need to be captured by using a more detailed study of probability distributions. Such analysis is one of the issues left for future research.

During implementation of the decision support system, the preferences of the decision makers, and/or public may change, or new ideas of experts could be produced. In order to control such changes, the system must be constantly monitored to ensure that the chosen parameters are still relevant. As soon as they change, the feedback in the DSM should be witnessed.

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ДОСЛІДЖЕННЯ УПОДОБАНЬ НАСЕЛЕННЯ ЩОДО ПОСЛУГ МІСЬКИХ ПАРКІВ І ЗЕЛЕНИХ ЗОН У КОНТЕКСТІ МІСЬКОГО ЛІСІВНИЦТВА

Розглянуто генезис і сутність концепції міського лісівництва, проаналізовано значення зелених зон у формуванні природного і культурного довкілля міст. Для дослідження уподобань населення щодо інтегрованого багатоцільового використання ресурсів і послуг міських природних систем застосовано метод концептуально-змістовного когнітивного картування на прикладі Регіонального ландшафтного парку "Знесіння".

Ключові слова: міське лісівництво, метод концептуально-змістовного когнітивного картування, уподобання, міські зелені зони.