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LOCATION PRIORITIZATION BY MEANS OF MULTICRITERIA SPATIAL DECISION-SUPPORT SYSTEMS: A CASE STUDY OF FOREST FRAGMENTATION-BASED RANKING OF FOREST ADMINISTRATIVE AREAS

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Abstract. Forest and conservation managers as decision-makers must deal with many competing criteria in order to find optimal solutions which best describe sustainable forest development. The aim of the study was to elaborate a framework for forest fragmentation-based forest administrative area ranking in order to support sustainable forest development. In this paper there is presented and discussed a two-stage multiple-criteria spatial decision-support system (MC–SDSS), employing it to locate a potential forest administrative area under different forest fragmentation conditions. Lithuanian state forest enterprises were selected as forest administrative areas and used as alternative options for ranking. Amount of forest areas, representing different forest fragmentation components (edge, perforated, undetermined, interior, patch, and transitional) in each state forest enterprise area, was taken as a criterion for alternative evaluation. Calculations of criterion significance were performed. Ranks for state forest enterprises were defined using technique for order preference by similarity to ideal solution (TOPSIS) and simple additive weighting (SAW) method. Results of this study suggest that forest fragmentation-based ranking of forest administrative regions is so important that it could potentially influence ecological processes during recurring forest development.

Keywords: forest fragmentation, landscape connectivity, multiple-criteria, decision support, weighting techniques, alternative options, preference ratios, criteria importance, area prioritization.

1. Introduction

Forest fragmentation pattern is important, as there are many animal and plant species, requiring certain habitat sizes, edge zones and characteristics of forest stands (Grashof-Bokdam 1997; Gibbs 1998). Human caused forest fragmentation could be either temporary after clearing and replanting the forest areas or long-lasting when caused by the expansion of agricultural, urban areas. Fragmentation of forest land has historically occurred in many countries, but for several decades till now the forest area is expanding (MCPFE 2007). However, increase of total forest area may be accompanied by the decrease of core forest and increased perforation or patchiness of forest areas (Kozak *et al.* 2007). Thus, understanding of spatial patterns of forest fragmentation is important for assessment of the ecosystem's quality. Aiming to maintain ecological balance and promoting economical development, it is necessary to strengthen the spatial connections among the landscape units whose functions are similar (Chang *et al.* 2005).

The growing awareness of negative effects of habitat fragmentation has resulted in rapidly increasing number of management actions such as traditional forest establishment initiatives in unproductive or poverty land. However, not attentive forest establishment may affect existing forest fragmentation pattern representing different density, connectivity and resources, moreover, may be harmful for species of "open" terrain. Thus sustainable forest establishment is a difficult and complex process, requiring of evaluation of many different usually conflicting criteria. There are growing demands of scientific tools to enhance the ecological, environmental, economic, recreational and other socially important values of state forests by managing them in accordance with the principles of sustainable landscape use and by rational use, restoration and enlargement of forest resources (Atmis *et al.* 2007; Alkan *et al.* 2009). However, comprehensive studies considering the forest fragmentation for the region are still lacking. Urgent action for conservation planning based on systematic place prioritization criteria is needed (Sanchez-Cordero *et al.* 2005). There are wide ranges of indices that can be used for place prioritization (Vogelmann 1995; Trani and Giles 1999; Wickham *et al.* 1999). However, applying of prioritization techniques for given alternatives without assessment of criteria importance must be cautious, in order to avoid misleading perceptions, index interceptions and redundancy with other similar indices (Lindenmayer and Fischer 2006; Zavadskas, Antuchevičienė 2006; Zavadskas *et al.* 2007; Turskis 2008).

The objectives of this study are to provide a framework for forest fragmentation based prioritization (ranking) of administrative forest areas by using both a tightly

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integrated multiple criteria decision making (thereafter MCDM) and a geographic information system (thereafter GIS) approaches with general decision support input. Such framework could be useful for forest and conservation managers as decision makers which must deal with many competing criterions in order to find optimal solutions which best describe ecologically and economically sustainable forest establishment.

2. Material and methods

2.1. An approach to spatial decision support system for the assessment of criteria based area ranking

The main role of multiple criteria spatial decision support systems (thereafter MC–SDSS) is to deal with the difficulties that human decision-makers have encountered in handling large pieces of complex information in a consistent way (Yoon and Hwang 1995). Two-staged MC–SDSS as one of spatial solution support systems (thereafter SDSS), were used to locate a certain administrative forest areas under different forest fragmentation conditions by using tightly integrated GIS and MCDM approaches (Fig. 1). In this study Lithuanian state forest enterprise areas were selected as forest administrative areas.

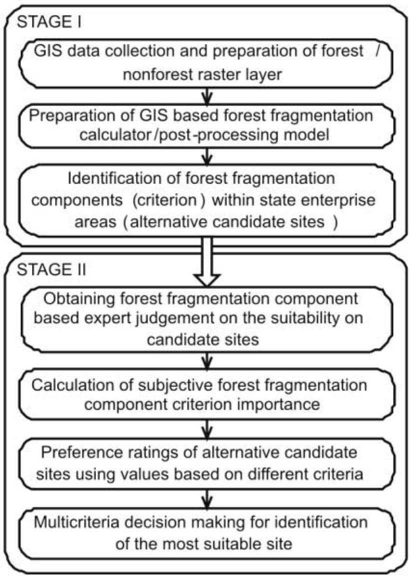

Fig. 1. Decision flowchart for spatial multicriteria analysis

The first-stage post-processing analysis makes use of the forest fragmentation map in GIS in conjunction with forest fragmentation component variables leading to support the second-stage state enterprise area ranking analysis based on MCDM methods.

It is desirable that the geographical data management and analysis component would contain a robust set of tools that are available in full fledged GIS systems. (Ascough *et al*. 2002). Thus, GIS software package from ESRI – ArcGIS® Spatial Analyst extension and custom Python based application developed during this study for performing of map algebra operations and determination of forest fragmentation components within state forest enterprise areas.

In order to perform state forest enterprise area ranking (based on forest fragmentation component importance criterion) and assess the compatibility of framework, custom SAW and TOPSIS methods based extension MC-SDSS for ArcGIS® software has been developed during this study. A tight MC–SDSS coupling strategy (Malczewski 1999) has been applied (Fig. 2).

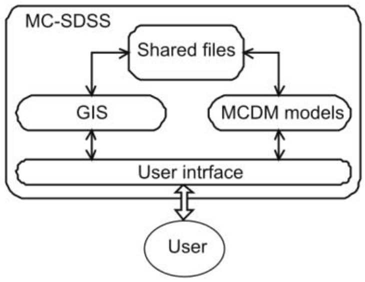

Fig. 2. Tight MC-SDSS coupling strategy

Tightly integrated MC–SDSS allows GIS and MCDM components to run simultaneously and to share a common database; therefore, program control remains within the GIS when performing the MCDM analysis (Ascough *et al.* 2002).

For state enterprise forest areas as candidate alternative sites, preference ratings were calculated by using the implemented decision aiding methods followed by Jakimavičius and Burinskienė (2007) descriptions. These methods are simple and appear as most often used multi-attribute decision techniques (Malczewski 1999). Methods for implementation in GIS were selected because basic variable inputs for these methods are the same. Though, different standardization/weighting techniques may lead to different results (Zavadskas *et al.* 2007).

2.2. Data collection and forest fragmentation method

CORINE land cover GIS database of the year 2000 with a minimum mapping unit of 25 ha (hereafter, "CLC") was used. Standard methodology of CLC2000 database has been specified in several successive versions and updates of its technical documentation (Heymann *et al.* 1994; Perdigao and Annoni 1997; Bossard *et al.* 2000).

National Lithuanian CLC land cover contains 32 (of the total 44 defined) standard land cover classes in the 3rd level of CLC nomenclature (Vaitkus 2004). In this study Lithuanian CLC broad-leaved (CLC code – 311), coniferous (312) and mixed forest – (313) were grouped into one general forest class ("*F*"), whereas the remaining classes – into one non-forest class ("*N*"). Inland and marine waters were treated as missing data values ("*M*"), so they did not increase the forest fragmentation during the analysis. Then Lithuanian CLC vector layer was processed into a raster grid (spatial resolution 30 m = 0.09 ha pixel^{-1}). National Lithuanian forest enterprise vector layer which contain state-owned forests attributed to 42 state forest enterprises were used for overlay analysis with forest fragmentation component map.

Fragmentation method are based on percolation theory assuming a random distribution of forest in a landscape (Riitters *et al.* 2002; Wade *et al.* 2003). For assignment of fragmentation metrics, the rule based block statistics were applied by following original Riitters *et al.* (2000) forest fragmentation pattern descriptions. Measurements identifying the patterns of forest fragmentation were performed based on the proportion of forest (P_f) and the forest pattern connectivity (P_{ff}) values within a set of non overlapping sliding window (hereafter – "block") in size of 27×27 pixels or 65.61 ha (at regional 1:50 000 scale). The first is P_f, which is the ratio of the number of forest pixels over the total number of pixels within the landscape that are not water ("*M*"). The second is P_{ff}, which is the ratio of the number of pixel pairs in cardinal directions that are both forest over the number of pixel pairs in cardinal directions that are either both forested or one is forested. Because they are proportions, both P_f and P_{ff} range from 0 to 1. After block statistics appliance P_f and P_{ff} values were assigned to the corresponding block.

The basic algorithm of fragmentation component delineation within a given block is presented in Fig. 3. For calculation clearance computation example of fragmentation component metrics (P_f and P_{ff} values) within a 5×5 pixel landscape is presented in Fig. 4.

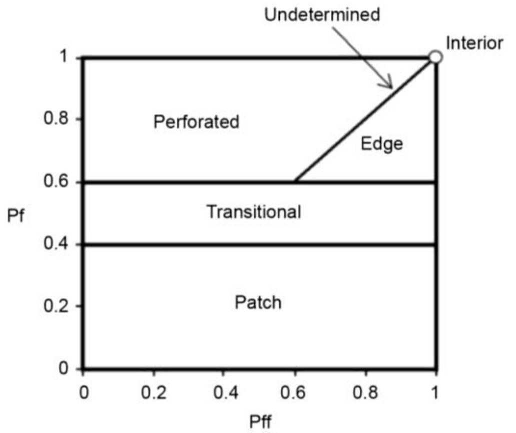

Fig. 3. The model used for identification of forest fragmentation components based on local measurements of P_f and P_{ff} within a given block (adapted from Riitters *et al.* 2000 – Erratum 2)

Calculation of proportion of forest P_f within given block:

$$P_f = \sum "F" / \sum "F" + \sum "N". \quad (1)$$

Calculation of forest connectivity P_{ff} within given block:

$$P_{ff} = \sum \{FF\} / \sum \{FF\} + \sum \{FN\}. \quad (2)$$

Determination rules of six forest fragmentation patterns are: *Edge*, if P_f >0.6 and $P_f - P_{ff}$ <0; *Perforated*, if P_f >0.6 and $P_f - P_{ff}$ >0; *Undetermined*, if P_f >0.6 and $P_f = P_{ff}$; *Interior*, if P_f = 1; *Patch*, if P_f <0.4; *Transitional*, if $0.4 \leq P_f \leq 0.6$ (Riitters *et al.* 2000).

The assignment of fragmentation component to landscapes started with calculation of P_f for the entire dataset. P_f thresholds were used for definition of interior (D), patch (E) and transitional (F) fragmentation components. For definition of edge (A), perforated (B) and undetermined (C) fragmentation components, $P_f - P_{ff}$ resulting value thresholds used. Calculations in order to define fragmentation component for landscapes: (A) P_f = 0.619 and $P_f - P_{ff}$ = –0.131; (B) P_f = 0.619 and $P_f - P_{ff}$ = 0.171; (C) P_f = 0.909 and $P_f - P_{ff}$ = 0; (D) P_f = 1; (E) P_f = 0.238; (F) P_f = 0.476. According to given example, computations of fragmentation component metrics (P_f and P_{ff} values) were performed for 42 state forest enterprises. Amount of forests with different fragmentation components in each state forest enterprise area were defined.

3. Forest fragmentation based ranking of state forest enterprise areas

3.1. Criteria and their importance assessment

Forests were classified as certain fragmentation components within blocks in 42 state forest enterprise areas. In order to perform ranking of state forest enterprises according to their forest fragmentation condition, the importance of fragmentation component as a criteria and function has been defined (Table 1). The importance of forest fragmentation components was estimated by using largest area size of all fragmentation components within all state forest enterprises and assumed as expert questioning.

Summary statistics for all fragmentation component area within state forest enterprises as experts' questioning were performed (Table 2).

Fig. 4. Illustration of measurement identification: edge (A), perforated (B), undetermined (C), interior (D), patch (E), and transitional (F) fragmentation components within six blocks. Whereas "*F*" – forest, "*N*" – non-forest and "*M*" – missing pixels. Heavy solid lines indicate {*FN*} connection, light solid lines – {*FF*}, no lines – {*NN*}, {*MM*} pixel edge types. {*NN*}, {*MM*} and dashed lines are not used in calculations

Table 1. Importance of criteria

No.	Criteria description	Function
R1	Amount of Edge forest (in each state forest enterprise) [ha]	maximize
R2	Amount of Perforated forest (in each state forest enterprise) [ha]	maximize
R3	Amount of Interior forest (in each state forest enterprise) [ha]	maximize
R4	Amount of Patch forest (in each state forest enterprise) [ha]	maximize
R5	Amount of Transitional forest (in each state forest enterprise) [ha]	maximize

Table 2. Results of experts' questioning

Expert No.	Criteria				
	R1	R2	R3	R4	R5
$E1_{Biržų}$	1	5	3	4	2
$E2_{Veisiejų}$	2	5	3	1	4
$E3_{Ignalinos}$	2	5	4	1	3
$E4_{Kaišiadorių}$	2	5	4	1	3
$E5_{Kauno}$	2	5	4	1	3
$E6_{Prienų}$	2	5	4	1	3
$E7_{Raseinių}$	2	5	4	1	3
$E8_{Tauragės}$	2	5	4	1	3
$E9_{Trakų}$	2	5	4	1	3
$E10_{Šiaulių}$	2	5	4	1	3
$E11_{Šilutės}$	2	5	4	1	3
$E12_{Jurbarko}$	2	5	4	1	3
$E13_{Alytaus}$	2	5	4	1	3
$E14_{Druskininkų}$	1	5	2	3	4
$E15_{Valkininkų}$	2	5	4	1	3
$E16_{Šalčininkų}$	2	5	4	1	3
$E17_{Marijampolės}$	2	5	4	1	3
$E18_{Šakių}$	2	5	4	1	3
$E19_{Rietavo}$	2	5	4	1	3
$E20_{Joniškio}$	2	5	4	1	3
$E21_{Tytuvėnų}$	3	5	4	1	2
$E22_{Kupiškio}$	2	5	4	1	3
$E23_{Jonavos}$	2	5	4	1	3
$E24_{Dubravos}$	2	5	4	1	3
$E25_{Kazlų\ Rūdos}$	1	5	3	2	4
$E26_{Švenčionėlių}$	1	5	3	2	4
$E27_{Ukmergės}$	1	5	4	3	2
$E28_{Varėnos}$	1	5	2	3	4
$E29_{Kretingos}$	1	5	4	3	2
$E30_{Kėdainių}$	2	5	4	1	3
$E31_{Panevėžio}$	2	5	4	1	3
$E32_{Radviliškio}$	2	5	4	1	3
$E33_{Nemenčinės}$	1	5	3	2	4
$E34_{Mažeikių}$	1	5	4	3	2
$E35_{Telšių}$	1	5	4	3	2
$E36_{Pakruojo}$	2	5	4	1	3
$E37_{Utenos}$	1	5	4	3	2
$E38_{Anykščių}$	2	5	4	1	3
$E39_{Zarasų}$	2	5	4	1	3
$E40_{Kuršėnų}$	2	5	4	1	3
$E41_{Rokiškio}$	1	5	4	3	2
$E42_{Vilniaus}$	2	5	4	1	3
t_{sum}	73	210	159	64	124
t_{avg}	1.74	5.00	3.79	1.52	2.95

The lowest value means that the criterion is most important, the highest value mean that the criterion is least important.

$$\sum t_{sum} = 630\ ;\ \sum t_{avg} = 15.$$

Calculation of rank sum:

$$t_{sum,i} = \sum_{j=1}^{l} t_{ij}\ , \quad (3)$$

$$i = 1,2..n,\ j = 1,2.l,\ n = 5,\ l = 42\ .$$

Calculation of rank average:

$$t_{avg,i} = t_{sum,i} / l\ . \quad (4)$$

Calculation of criterion importance:

$$g_i = t_{avg,i} / \sum_{i=1}^{n} t_{avg,i}\ , \quad (5)$$

$$\underline{q_i} = 1 - g_i\ , \quad (6)$$

$$\sum_{i=1}^{n} \underline{q_i} = 4\ ,$$

$$q_i = \underline{q_i} / \sum_{i=1}^{n} \underline{q_i}\ . \quad (7)$$

The higher the importance value *q*, the more important criteria is.

Results of calculations are presented in Table 3.

Table 3. Results of calculations

Variable	Criteria				
	R1	R2	R3	R4	R5
$t_{sum,i}$	73	210	159	64	124
$t_{avg,i}$	1.74	5	3.79	1.52	2.95
g_i	0.116	0.333	0.252	0.102	0.197
$\underline{q_i}$	0.221	0.167	0.187	0.225	0.201
q_i	0.884	0.667	0.748	0.898	0.803

Calculation of criterion set of sum square:

$$S = \sum_{i=1}^{n} \left(\sum_{j=1}^{l} t_{ij} - 1/n \times \sum_{i=1}^{n} \sum_{j=1}^{l} t_{ij} \right)^2 , \quad (8)$$

$$S = 14802\ .$$

Estimation of concordation coefficient:

$$W = 12 \times S / l^2 (n^3 - n)\ , \quad (9)$$

$$W = 0.839\ .$$

Validation of experts questioning:

$$W > 0, W = 0.839 > 0.$$

Testing condition of importance:

$$\sum q_i = 1, \sum q_i = 0.221 + 0.167 + 0.187 + 0.225 + 0.201 = 1.$$

The sum of criterion importance values for forest fragmentation components should be equal 1. This is mandatory condition for further analysis.

3.2. Results of simple additive weighting application in GIS

A fragment of summarized forest fragmentation component pixels (size of 27×27–30 m pixels or 65.61 ha) within state enterprise areas for GIS application is shown in Table 4.

Table 4. Fragment of forest fragmentation statistical data (area of forest fragmentation component (ha)) within state forest enterprises

State forest enterprise	Criteria				
	R1	R2	R3	R4	R5
A_1 Telšiai	685	10	81	1493	539
A_2 Tauragė	411	7	109	740	245
A_3 Joniškis	211	3	36	469	114
Importance (*q*)	0.221	0.167	0.187	0.225	0.201
Function	max	max	max	max	max

The input data used for calculations are: state forest enterprises (A_i) as alternatives, criteria (R_i) and their importance (q). Criteria matrix is normalized under the following conditions:

If criterion is maximized:

$$X_{ij} = X_{ij} / X_j^{\max}. \quad (10)$$

If criterion is minimized:

$$X_{ij} = X_j^{\min} / X_{ij}. \quad (11)$$

Normalized criteria matrix is shown in Table 5.

Table 5. Normalized criteria matrix for SAW calculation

State forest enterprise	Criteria (normalized)				
	R1	R2	R3	R4	R5
A_1 Telšiai	1	0.67	0.16	0.97	1
A_2 Tauragė	0.60	0.47	0.21	0.48	0.45
A_3 Joniškis	0.31	0.20	0.07	0.31	0.21

After the matrix is normalized, each criterion of a certain alternative is multiplied by its importance. The multiplied criteria are summed for each alternative. Ranking of state forest enterprise areas based on present forest fragmentation component statistics:

$$\text{A}_1\ \text{Telšiai} = 1 \times 0.221 + 0.67 \times 0.167 + 0.16 \times 0.187 + 0.97 \times 0.225 + 1 \times 0.201 = 0.780.$$

Respectively:

$$\text{A}_2\ \text{Tauragė} = 0.449;$$

$$\text{A}_3\ \text{Joniškis} = 0.225.$$

The ideal solution is the collection of the ideal scores (or ratings) in all attributes considered. The best alternative, are with the highest value. The largest value means the best option for forest establishment, neglecting which forest fragmentation component is needed for expanding. The alternatives can then be ranked according to the value in descending order. The priority row of options for given fragment:

A_1 Telšiai > A_2 Tauragė > A_3 Joniškis.

3.3. Results of technique for order preference by similarity to ideal solution application in GIS

For normalization of statistical data (see Table 4) the following formula were used.

$$X_{ij} = X_{ij} / \sqrt{\sum_{j=1}^{i} X_{ij}^2}. \quad (12)$$

Calculation of denominator values for certain criteria are presented in Table 6.

Table 6. Results of denominator value calculations

Variable	Criteria				
	R1	R2	R3	R4	R5
$\sqrt{\sum_{j=1}^{i} X_{R_{ij}}^2}$	826.24	12.57	140.49	1731.07	602.94

Normalized criteria matrix for TOPSIS calculation is shown in Table 7.

Table 7. Normalized criteria matrix for TOPSIS calculation

State forest enterprise	Criteria (normalized)				
	R1	R2	R3	R4	R5
A_1 Telšiai	0.83	0.80	0.58	0.86	0.89
A_2 Tauragė	0.50	0.56	0.78	0.43	0.41
A_3 Joniškis	0.26	0.24	0.26	0.27	0.19

In order to get weighted matrix, criteria matrix values are multiplied by the matrix of importance values.

$$P^* = [X] \times [q], \quad (13)$$

$$P^* = \begin{bmatrix} 0.183 & 0.133 & 0.108 & 0.194 & 0.179 \\ 0.110 & 0.093 & 0.145 & 0.096 & 0.082 \\ 0.056 & 0.040 & 0.048 & 0.061 & 0.038 \end{bmatrix}.$$

Normalized matrix is used for calculating and ideal positive (f_j^+) and ideal negative (f_j^-) variants.

Ideal positive variant. If the criterion is minimized, it is necessary to take the minimal value from each row. If the criterion is maximized – maximal value from each row (in study case all the criteria are maximized):

$$f_j^+ = \{0.183 \quad 0.133 \quad 0.145 \quad 0.194 \quad 0.197\}.$$

Ideal negative variant. If the criterion is minimized, it is necessary to take the maximal value from each row. If the criterion is maximized – minimal value from each row:

$$f_j^- = \{0.056 \quad 0.040 \quad 0.048 \quad 0.061 \quad 0.038\}.$$

Calculation of variant's deviation from the ideal positive variant.

$$L_j^+ = \sum_{i=1}^{n} \left(f_{ij} - f_j^+ \right)^2 . \tag{14}$$

Calculation of variant's deviation from the ideal negative variant.

$$L_j^- = \sum_{i=1}^{n} \left(f_{ij} - f_j^- \right)^2 . \tag{15}$$

Calculation of proportional variant's deviation from an ideal variant K_{BIT}:

$$K_{BIT} = L_j^- / \left(L_j^+ + L_j^- \right). \tag{16}$$

Table 8. Results of calculation of variants deviation from ideal positive and ideal negative variants as well as K_{BIT} values

Variable	Alternative options		
	A_1	A_2	A_3
$L_{A_i}^+$	0.037	0.309	0.591
$L_{A_i}^-$	0.554	0.282	0.000
K_{BIT,A_i}	0.937	0.478	0.000

The best alternative, are with the highest K_{BIT} value. The largest value means the best option for forest establishment, neglecting which forest fragmentation component is needed for expanding. Meanwhile this method gives and distances to ideal positive and to ideal negative variant for each given alternative as an intermediate solution. The alternatives can then be ranked according to the value in descending order. The priority row of options for given example:

A_1 Telšiai > A_2 Tauragė > A_3 Joniškis.

3.4. Forest fragmentation and area ranking results of study area

About 27.16% of all forest in study area was classified as Edge, 0.41% as Perforated, 8.10% as Interior, 47.96% as Patch, 16.37% as Transitional and 0% as Undetermined. It is important to note that using different landscape size for forest fragmentation assessment may lead to different results due scale and generalization effects (Riitters *et al*. 2002).

The regional scale patterns of forest fragmentation in Lithuania can be represented by mapping fragmentation components in 65.61 ha landscape size, as shown in Fig. 5. Fragmentation map compared with soil, relief data (Drobnys *et al.* 1981), suggest that most of the forest persist in the areas less favorable for agriculture, where soils are sandy, poor in nutrients, on sloping land or very wet. Similar association patterns were generally observed for other areas in Europe (Wulf 1998).

Analysis results at regional scale showed that most dominant forest component type assigned for forested area is Patch, less dominant Edge and Transitional forest types. The least dominant forest type is Interior. Less fragmented forest landscapes were found in the south-eastern and most fragmented landscapes were found on western and eastern parts of country.

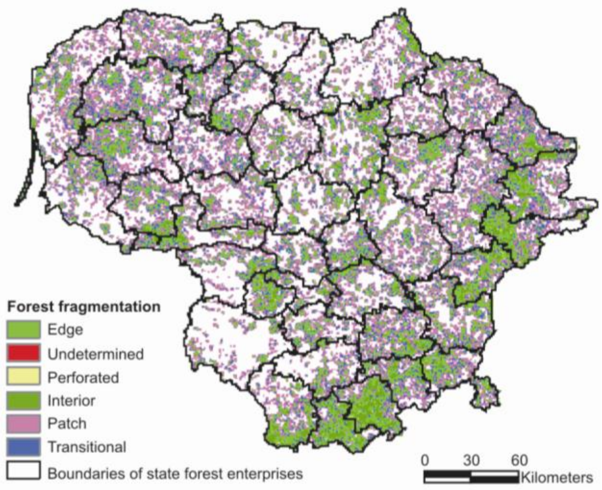

Fig. 5. Spatial distribution of Lithuanian forest fragmentation components at 65.61 ha blocks. Administrative boundaries of state forest enterprises are shown as reference

GIS based SAW and TOPSIS method used to calculate evaluation scores for forest enterprise areas as alternative options (table rows) based on expert defined forest fragmentation component assessment criteria (table columns). After the evaluation scores for alternative variants were calculated, the forest enterprise area ranking has been performed and calibrated results mapped by using standard ArcMap® tools (Fig. 6).

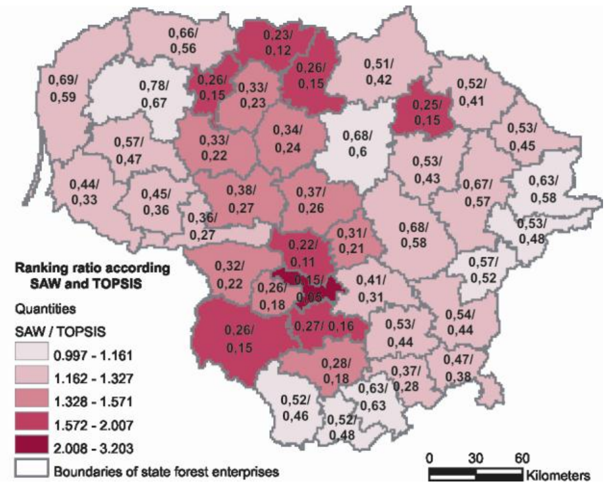

Fig. 6. Forest fragmentation component maximum area size based ranking of Lithuanian state forest enterprises

Ranking analysis results at regional scale showed that highest ranks are given for areas in less fragmented forest landscapes in the southern, eastern part of the country. Lowest ranks were assigned to most fragmented landscapes and found on the middle and northern part of country. Most cost effective forest establishment would be in state forest areas which have highest ranks. Lower ranks means that establishment of any forest fragmentation component may need more resources than in areas with higher ranks.

Inappropriate forest establishment may lead to negative influence on ecological processes in a forest landscape. The ranking could be used for planning funds, allocated to forest establishment, according to state forest enterprises.

4. Conclusions and discussion

First-stage analysis was limited to the forest/nonforest fragmentation. Using different block size for forest fragmentation assessment may lead to different results due generalization effect. Observed sensitivity of the forest fragmentation components to observation scale may indicate a general level of fragmentation. If forest is not fragmented, then increased block size will not alter composition of forest fragmentation components. If forest is fragmented, then increased block size will alter composition of forest fragmentation components. Thus, forest fragmentation are scale dependent.

The framework followed in this study differs from conventional methods of integrating GIS with MCDM, because approach follows tight integration approach rather than a loose. For second-stage analysis there may be applied many different standardization/weighting techniques such as TOPSIS, AHP, PROMETHEE, DEA, SAW (scoring) and others widely described in literature, and which can be used in MC–SDSS. Though, only SAW and TOPSIS methods were used for analysis. Different standardization/weighting techniques may lead to different results. Ranking process can lead to situations in which certain criteria may cause increased ambiguities in the decision making process due to lacking sufficient information or contradicting judgments. Meanwhile the discrepancy in the judgment between few experts can have a significant impact on the selection process, which can be minimized by having more experts to provide assessments on the decision criteria weights (Joerin and Musy 2000; Geneletti 2004; Malczewski 2004; Kangas *et al.* 2005; Chang *et al.* 2007).

In current study, maximization function was selected for all given forest fragmentation component criteria in order to rank state forest enterprise areas. In order to perform forest fragmentation impact within study area on plant colonization (Robinson *et al.* 1995; Grashof-Bokdam 1997), animal movement (Belisle *et al*. 2001), predation or habitat suitability (Burke, Nol 2000) additional domain based estimation criteria and functions should be considered. Thus, understanding which criterion and under what conditions is important, remains a considerable research challenge.

Based on the study results, the following conclusions can be done:

1. Analysis results suggest that most dominant forest component type within study area assigned for forested area is Patch, and least dominant forest type is Interior. Less fragmented forest landscapes were in the south-eastern part of the country. Most fragmented forest landscapes were found on western and eastern part of country.

2. Ranking at regional scale showed, that highest ranks are given for areas in less fragmented forest. Lowest ranks were assigned to most fragmented landscapes. Lower ranks means that establishment of any forest fragmentation component may need more resources than in areas with higher ranks.

3. The elaborated framework could be successfully used for planning of forest establishment according to the forest fragmentation and other important criteria considered. The ranking could be used for planning funds, allocated to forest establishment, according to the state forest enterprises in order to seek ecological balance and suspense economical development of forest areas.

4. The GIS based SAW and TOPSIS tightly integrated approaches could be used for general forest forecasting with other criteria considered. Provided framework structure and tools could be easily adapted by the other countries in analyzing of forest administrative areas for prioritization. Control mechanisms provided for decision makers by custom MC-SDSS applications allow them introduce qualitative and subjective information during the evaluation and the solution processes.GIS data and domain based estimation criteria are necessary.

5. Study results can serve as illustrative material and a certain logical framework for local decision makers which may lead towards better understanding of decision ramifications.

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VIETOVIŲ PRIORITIZAVIMAS TAIKANT ERDVINES DAUGIATIKSLES SPRENDIMŲ PARAMOS SISTEMAS: MIŠKŲ ADMINISTRACINIŲ TERITORIJŲ RANGAVIMO MIŠKO FRAGMENTACIJOS PAGRINDU ATVEJO ANALIZĖ

A. Kučas

S a n t r a u k a

Miškų ir saugomų teritorijų valdytojai, kaip sprendimų priėmėjai, ieškodami optimalių darnios miško plėtros sprendimų, dažnai susiduria su įvairiais, dažniausiai prieštaringai vertinamais, kriterijais. Šios studijos tikslas yra sukurti miško fragmentacija pagrįstus miškų administracinių teritorijų rangavimo metodikos metmenis darnią miško plėtrą lemiančių sprendimų priėmimui palengvinti. Pateikiama ir apibendrinama dviejų lygių erdvinių daugiatikslių sprendimų paramos sistema (*MC-SDSS*), skirta potencialiems miškų administraciniams vienetams su atitinkama miško fragmentacijos situacija nustatyti. Tyrimui kaip vertinimo alternatyvos buvo pasirinktos Lietuvos miškų urėdijų teritorijos. Alternatyvų vertinimo kriterijumi buvo pasirinktas skirtingų fragmentacijos tipų (miško pakraščio, prasiskverbiančio miško, nenustatyto miško, ištiso miško, retų miško želinių ir pereinamosios miško stadijos) miško plotas kiekvienoje miškų urėdijoje. Atlikti kriterijų reikšmingumo skaičiavimai. Prioritetų eilė miškų urėdijoms buvo nustatyta taikant įprastinio informacijos lygio *TOPSIS* ir *SAW* metodus. Tyrimai parodė, kad miško fragmentacija pagrįstas miškų administracinių vienetų rangavimas yra svarbus ir potencialiai gali turėti įtakos ekologiniams procesams, vykdant periodinius miško veisimo bei atnaujinimo darbus.

Reikšminiai žodžiai: miško fragmentacija, kraštovaizdžio sąsajos, daugiatiksliai kriterijai, sprendimų parama, svertiniai metodai, alternatyvieji variantai, prioritetų įverčiai, kriterijų reikšmingumas, vietovės prioritizavimas.

ПРИОРИТИЗАЦИЯ МЕСТНОСТЕЙ С ИСПОЛЬЗОВАНИЕМ ПРОСТРАНСТВЕННЫХ МНОГОЦЕЛЕВЫХ СИСТЕМ ПОМОЩИ В ПРИНЯТИИ РЕШЕНИЙ: АНАЛИЗ СЛУЧАЯ РАНЖИРОВАНИЯ ЛЕСНЫХ АДМИНИСТРАТИВНЫХ ТЕРРИТОРИЙ НА ОСНОВАНИИ ФРАГМЕНТАЦИИ ЛЕСА

А. Кучас

Резюме

Управляющие лесными хозяйствами и охраняемыми территориями как лица, ответственные за поиск и принятие оптимальных решений, способствующих сбалансированному развитию леса, нередко встречаются с разными, чаще всего противоречивыми критериями оценки. Целью настоящего исследования было создание каркаса методики ранжирования лесных административных территорий на основании фрагментации леса, предназначенной для облегчения принятия решений, обуславливающих сбалансированное развитие леса. В статье представлена и обобщена пространственная многоцелевая двухуровневая (MC-SDSS) система помощи в принятии решений, предназначенная для определения потенциальных лесных административных единиц с соответствующей ситуацией фрагментации леса. Для исследования были выбраны территории лесничеств Литвы как альтернативный вариант оценки. В каждом лесничестве были выбраны участки леса с разными типами фрагментации (окраины леса, проникающего леса, неопределенного леса, сплошного леса, пятнистого покрытия лесом и леса переходной стадии) в качестве критериев оценки альтернативных вариантов. Проведены подсчеты значимости критериев. Методами обычного уровня информации TOPSIS и SAW был определен ряд приоритетов. Исследования показали, что ранжирование административных единиц, основанное на фрагментации леса, является важным, так как оно потенциально может оказывать влияние на экологические процессы, происходящие при проведении периодических работ по созданию и обновлению леса.

Ключевые слова: фрагментация леса, ландшафтные связи, многоцелевые критерии, помощь в принятии решений, методы оценки, альтернативные варианты, оценки приоритетов, значимость критериев, приоритизация местности.

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