Application of Fuzzy and Classical Multi-Criteria Decision-Making Methods in Assessing the Forest Area Preservation Level of Romania's Counties

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Abstract

With over a quarter of its territory covered by forest, Romania stands out as a European country with a medium forest area extension. Despite the fact that the forest area has increased since 2008, there are counties that are affected by forest loss caused by outlawed forest cutting and other factors. This calls for improved knowledge and critical spatial planning of the forest area at county level. The aim of this study is to assess the forest area preservation level of Romania's 41 counties using fuzzy and classical Multi-Criteria Decision-Making methods. The paper includes inferences regarding the distribution of the illegal forest cutting cases at county level that link forest management issues with the forest area preservation level. Fuzzy Analytic Hierarchy Process (FAHP) is applied to weigh factors related to the changes of forest provision, forest loss and forest regeneration processes, dimensions of forest exploitation and illegal forest cutting cases using data referring to 1990-2017. The alternatives are represented by the 41 counties of Romania and are evaluated by the use of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The results are integrated with GIS and the choropleth map may serve as a powerful visual and practical tool for identifying the counties with pressing forest loss issues. Results show the counties with the lowest levels of forest area preservation were Argeş, Prahova and Gorj. Harghita, Brăila and Suceava counties recorded the highest levels of forest area preservation. While some of the counties that rank among the least in terms of forest area preservation are also altered by massive illegal forest cutting, there are others that serve as counter-examples. The discrepancies are explained by the provisional character of the illegal forest cutting data. Our study shows significant practical importance, pointing out the administrative units of Romania that need to take urgent action in order to mitigate the problem of forest loss and to better their forest management.

Keywords: forest area preservation, Fuzzy Analytic Hierarchy Process, Technique for Order Preference by Similarity to Ideal Solution, forest management, illegal forest cutting, Romania

Introduction

Forests are one of the most important natural resources, as they fulfil various ecosystem services, e.g. regulation, provisional, cultural and supporting services (European Commission 2013, Garrido et al. 2017, Elbakidze et al. 2017). Also, forests have become increasingly valued by humans due to their beneficial effects on physical and mental health (European Commission 2013, Elbakidze et al. 2017). Considering the various ecosystem services that forests provide, one may associate the idea of extended areas of forests with richness of both material and abstract kind. However, the balance between forest exploitation and forest preservation is not easily achieved and constitutes a sensitive debate subject (Angelstam et al. 2018, Naumov et al. 2018).

At continental level, Romania ranks in the upper half of the hierarchy regarding forest cover, with more than a quarter (27.53 %) of its territory represented by forests (Forest Europe 2015, NIS 2017). According to the State of Europe's Forests (2015), Romania's forest cover was 6.9 million ha. However, in 2017, the forest cover of Romania was 6.5 million ha according to the National Institute of Statistics (NIS 2017) and the Ministry of Waters and Forests (MAP 2017). This value is lower than the European forest cover average of 32 % and lower than the EU-28 forest cover average of 42 % (Eurostat 2018a, MAP 2017, Eurostat 2018, NIS 2017). According to Romanian law the term of "forest cover" is extended to include not only land covered by forests, but also land designated to reforestation, as well as areas occupied by ponds or riverbeds and other types of land use

(Forest Act 2015). Thus, the actual area occupied by common forests is of 6.4 million ha, meaning 97.57 % of the forest cover of Romania (NIS 2017). In this paper, forest areas are referred to as areas of more than 0.25 ha covered by trees that reach a minimum height of 5 m at maturity in normal conditions (Forest Act 2015).

Although the forest area of the country has steadily increased since 2008, there are counties that have registered declines in forest area between 1990 and 2017. This increase is mostly artificial, being based on the progressive placement of degraded land into the forestry fund or the restoration of wooded lawns (Niţă 2015, MAP 2017). The loss of forest area at county level is a consequence of various causes, such as the unsuitability of the forest management legislation, the ineffectiveness of the recently created Forest Inspectorates and institutional instability of the forestry sector (Popa et al. 2019), high rates of corruption (Roman 2009, Bouriaud and Marzano 2012, Niţă 2015), numerous illegal forest cutting cases (Greenpeace Romania 2009-2017, Bouriaud and Marzano 2012, Niţă 2015), and defective perspectives of the private owners regarding the value of the forest (Abrudan 2012). An important factor that has contributed to forest mismanagement is the negative or the neutral position of forest inspectors to engage in law enforcement efforts. Results from Popa et al. (2019) on the theory of planned behaviour show that this situation is determined by the "unsuited training of personnel, improper planning and management at organizational level and unsuited legislation".

In 2017, the number of illegal forest cutting cases reported at national level reached 12487, or 32 % higher than the previous year. Also, the number of forestry-related infractions (8461) were 62.02 % higher than in 2016 (Greenpeace Romania 2017). Between 2009 and 2017, the counties that registered the highest average number of illegal cutting cases were the following ones: Argeş (2708), Bacău (15383.50), Mureş (1578.83), Gorj (1239.50) and Prahova (1230.16). Among the lowest-ranking ones there were: Brăila (39), Teleorman (68), Botoşani (83.16), Călăraşi (85) and Constanţa (90.66) (Figure 1) (Greenpeace Romania 2009-2017). Nevertheless, the actual total number of illegal forest cuttings cases remains unknown.

Concurrently, the number of the forestry-related violations that are investigated by the authorities is on the rise (20835 investigated cases in 2017, or 15.07 % higher than in 2016). This tendency is correlated with the efforts of the authorities to reduce illegal forest cuttings. As society also plays an important role in the endeavour to achieve better forest management, two smartphone applications as: i) The Forest Radar, and ii) Forest Inspector were created and citizens are encouraged to report and verify the legal status of wood products, transportation and/or commercialisation by calling 112. In 2017, the number of phone calls regarding the legality of wood products transportation reached 10299 and the Forest Inspector application was installed by more than 100,000 people. Out of all reports of potential illegal activity, 23.55 % have been confirmed as issues of illegal forest cutting, proving the usefulness of these services and applications (Greenpeace Romania 2009-2017).

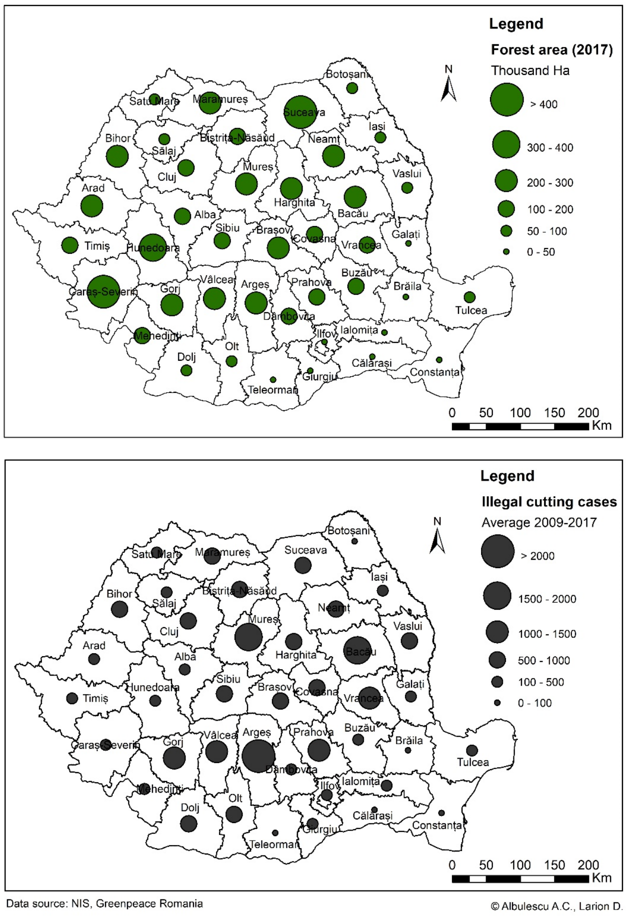

Figure 1. The forest area and the illegal cutting cases at county level

Another step forward concerning the task of increasing the preservation level of Romania's forest areas consists in the development of fuzzy and classical Multi-Criteria Decision-Making tools (e.g. Kaya and Kahraman 2011, Saaty 2008).

The aim of this paper is two-fold: 1) to assess the forest area preservation level of Romania's 41 counties using a combination of classic and fuzzy Multi-Criteria Decision-Making (MCDM) methods, and ii) to develop a tool that can be used to aid forest area preservation. The term of forest area preservation refers to the maintenance of the forest area in time, at county scale, regardless of the type or status of the forests. In other words, forest area preservation is the opposite of forest disturbance, which is defined as “loss of forest cover due to forest harvest and natural disturbances” (Munteanu et al. 2016).

Materials and Methods

Applying a fuzzy and classic MCDM framework

In order to facilitate a proper understanding of the current assessment, an introduction to these methods is required. The combination of fuzzy and classical MCDM methods provides a comprehensive and well-structured framework that integrates contrasting factors and addresses both the fuzziness of the data involved, especially the one concerning the illegal forest cutting cases, and the need to evaluate a fairly high number of alternatives.

AHP

The Analytic Hierarchy Process (AHP) developed by T. Saaty in the 1970s is a MCDM method that organises the elements of a problem into a hierarchical structure. A clearly defined goal is placed at the uppermost level, and it is followed by the level of the factors/criteria that relate to the goal and by the level of the alternatives which are evaluated with respect to each of the criteria (Saaty 2008). The upper levels do not rely on the lower ones and all the elements of a level are independent of each other (Shapiro and Koissi 2015). The elements on the same level are evaluated by the use of pair-wise comparisons which are organised in comparison matrices. The pair-wise comparisons are represented by crisp numbers and their reciprocals, according to a predefined scale (Saaty 2008).

The AHP is easy to understand and implement, and because it encompasses a consistency checking mechanism, its results prove to be fairly reliable. Its flexibility and logical structural design explain the various applications of the method in the fields ranging from risk assessment to site suitability analyses and marketing strategies. However, the subjectivity of the decision-maker, the vagueness of the data and other methodological shortcomings place the accuracy of the AHP results under question (Shapiro and Koissi 2015).

FAHP

The Fuzzy AHP (FAHP) emerges as an extension of the AHP which addresses the aforementioned issues. While classical logic regards the truth as a binary concept, fuzzy logic is defined as a multi-valued logic that distinguishes itself by replacing crisp sets of data with fuzzy ones. These fuzzy data sets allow for partial membership, resembling human thinking more than classic sets (Zadeh 1965).

The crisp numbers of the comparison scale are replaced by fuzzy numbers in the form of Triangular Fuzzy Numbers (TFNs) or Trapezoidal Fuzzy Numbers (Trapezoidal FNs). This type of numbers is a better match for the uncertainty inherently involved in the comparison process, as they introduce the notion of partial membership (Zadeh 1965, Shapiro and Koissi 2015). Among the strengths of the FAHP there are the possibility to use interval judgements, which are more reliable than fixed-value judgements specific to Boolean logic, and the use of linguistic variables that are easy to work with (Jia et al. 2014, Shapiro and Koissi 2015) (Table 1).

Table 1. The scale of preferences used for factor comparisons (Zhu et al. 1999, Anagnostopoulos et al. 2007)

Linguistic variable	Crisp number	TFNs	Reciprocal TFNs
Equally preferred	1	(1, 1, 1)	(1, 1, 1)
Equally to moderately preferred	2	(1, 2, 3)	(1/3, 1/2, 1)
Moderately preferred	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Moderately to strongly preferred	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Strongly preferred	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Strongly to very strongly preferred	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Very strongly preferred	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Very strongly to extremely preferred	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Extremely preferred	9	(8, 9, 9)	(1/9, 1/9, 1/8)

In this paper, the Chang FAHP model was used to weigh the considered factors. The pair-wise comparisons of the factors are represented by TFNs corresponding to the linguistic variables illustrated in Table 1. A TFN is defined by three real numbers ($l \leq m \leq u$) that define the lower value (l) and the upper value (u) of the support of Z, and the modal value (m) of this number. Let Z be a TFN on R, defining its membership function $\mu_Z(x): R \rightarrow [0,1]$ as (Chang 1996):

$$\mu_Z(x) = \begin{cases} \frac{x}{m-l} - \frac{l}{m-l}, x \in [l,m], \\ \frac{x}{m-u} - \frac{u}{m-u}, x \in [m,u], \\ 0 \quad , otherwise. \end{cases} \quad (1)$$

If $Z_1 = (l_1,m_1,u_1)$ and $Z_2 = (l_2,m_2,u_2)$ are two distinctive TFNs, the arithmetic operations are to be implemented as follows (Chang 1996):

$$(l_1,m_1,u_1) + (l_2,m_2,u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad (2)$$

$$(l_1,m_1,u_1) \cdot (l_2,m_2,u_2) = (l_1 \cdot l_2, m_1 \cdot m_2, u_1 \cdot u_2) \quad (3)$$

$$(l_1,m_1,u_1)^{-1} \approx (\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}) \quad (4)$$

After the completion of the comparison matrix (M), the fuzzy synthetic extent (S_i) is computed by applying the fuzzy equivalent of the arithmetic mean (Chang 1996, Shapiro and Koissi 2015):

$$S_i = \sum_{j=1}^{m} M_{ij} \cdot \left[\sum_i^n \sum_j^m M_{ij}\right]^{-1} \quad (5)$$

The next step consists in comparing the fuzzy synthetic extent (S_i) using the degree of possibility that is $V(Z_1 \geq Z_2)$, as follows (Chang 1996):

$$V(Z_1 \geq Z_2) = \begin{cases} 1 & , if\ m_1 \geq m_2, \\ 0 & , if\ l_2 \geq u_1, \\ \dfrac{l_2 - u_1}{(m_1 - u_1) - (m_2 - l_2)} & , otherwise. \end{cases} \quad (6)$$

Both values of $V(Z_1 \geq Z_2)$ and $V(Z_2 \geq Z_1)$ are required for further computations. In the endeavour to determine the degree of possibility for S_i to be greater than k TFNs, the min operation is used (7) (Dubois and Prade 1980). The results are to be normalized in order to be used analogously to the ones that would have been obtained if the classical AHP had been applied (W).

$$V(S_i \geq S_1, S_2, S_3 \ldots S_k) = \min V(S_i \geq S_k) = w(S_i) \quad (7)$$

$$W = (w(S_1), w(S_2), w(S_3), \ldots w(S_n))^T \quad (8)$$

TOPSIS

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was introduced by C.L. Hwang and K. Yoon in 1981, as a method for solving Multiple Attribute Decision-Making problems (Hwang and Yoon 1981, Hwang et al. 1993). TOPSIS relies on the concept of a compromise solution that is located the closest to the positive ideal solution (A^+) and the furthest from the negative ideal solution (A^-). The compensatory character of the method is determined by the fact that pursuing the purpose of choosing the best alternative from a finite set, or ranking the alternatives of a finite set, conflicting criteria may be considered. From this point of view, there are monotonically increasing criteria (benefit criteria) and monotonically decreasing criteria (non-benefit or cost criteria) (Roszkowska 2011, Tzeng and Huang 2011, Pavić and Novoselac 2013).

Suppose X is the matrix of the alternatives' scores, having n columns and m lines, and that NX is the normalized matrix. The first K criteria of the assessment are benefit criteria and the rest of them are non-benefit criteria. The first step consists in normalizing these scores (9). The normalized matrix (NX) is multiplied by the vector comprising the normalized factors' weights (10). The new matrix (A) is then used to determine the positive ideal solution (A_j^+) and the negative ideal solution (A_j^-) for each of the n columns of the matrix (11), (12) (Pavić and Novoselac 2013).

$$NX_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} {X_{ij}}^2}} \quad (9)$$

$$A_{ij} = W_j \cdot NX_{ij} \quad (10)$$

$$A_j^+ = \begin{cases} \max\limits_i A_{ij} & for\ j = 1, \ldots, K \\ \min\limits_i A_{ij} & for\ j = K+1, \ldots, n \end{cases} \quad (11)$$

$$A_j^- = \begin{cases} \min\limits_i A_{ij} & for\ j = 1, \ldots, K \\ \max\limits_i A_{ij} & for\ j = K+1, \ldots, n \end{cases} \quad (12)$$

Then, the Euclidean distance to the positive ideal solution (d_i^+) and from the negative ideal solution (d_i^-) must be determined for each of the alternatives. Finally, by the use of the formula (15), the relative distance of each of the alternatives regarding the positive and the negative ideal solutions (D_i^+) is computed. These distances indicate the suitability of the alternatives with respect to the considered criteria. The ranking of the alternatives is obtained by ordering these distances (D_i^+) in decreasing order (Pavić and Novoselac 2013).

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (A_{ij} - A_j^+)^2} \quad (13)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (A_{ij} - A_j^-)^2} \quad (14)$$

$$D_i^+ = \frac{d_i^-}{d_i^+ + d_i^-} \quad (15)$$

Fuzzy and classic MCDM Analysis

These classical and fuzzy MCDM methods are applied in order to assess the forest area preservation level in all 41 counties of Romania. The results are integrated with the GIS tools (ArcMap software) to obtain a choropleth map that may serve as visual and practical tool for future forest loss mitigation at county level.

The seven factors considered relevant to the purpose of this study relate to forest provision, forest loss and forest regeneration processes, volume of harvested wood and illegal forest cutting cases, and were weighed using the FAHP (Figure 2).

It should be noticed that these factors indicate tendencies or average situations and some of them were

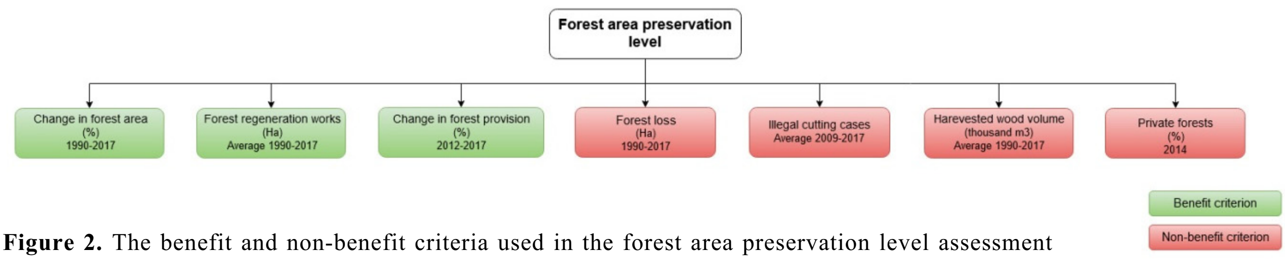

Figure 2. The benefit and non-benefit criteria used in the forest area preservation level assessment

computed for a maximum time interval of 28 years, corresponding to the time period of 1990-2017. The computation procedures are explained in Table 2, as some of the data provided by NIS or Greenpeace Romania required specific processing in order to be implemented. According to the goal of determining the highest forest area preservation level, the considered factors are regarded as benefit criteria, where high values indicate a high level of forest area preservation or non-benefit criteria, where high values suggest the contrary (Figure 2). The alternatives represented by Romania's counties are ranked using the TOPSIS method.

Table 2. The criteria used in the forest area preservation level assessment

Criteria/ABBREVIATION	Short Description	Data sources
Change in forest area/ CHANGE_FA %*	It represents the growth rate (%) of the forest areas during 1990-2017. Negative values indicate the decrease of the forest areas.	NIS, Own computation
Forest regeneration works/ REG_AV	This factor is computed as the average of the areas (ha) that underwent forest regeneration works in 1990-2017.	NIS, Own computation
Change in forest provision/ CHANGE_FP %*	It represents the growth rate (%) of the forest provision (forest area/population) of a specific county in 2012-2017. Negative values show the decrease of the forest areas in relation to the population.	NIS, Own computation
Forest loss/ F_LOSS*	It is computed by subtracting the forest areas that existed at county level in 2017 from those in 1990. Negative values indicate an increase in the forest areas.	NIS, Own computation
Illegal cutting cases/IC	This factor is computed as the average of the registered illegal cutting cases during 2009-2017.	Greenpeace Romania 2009-2017, Own computation
Harvested wood volume/ WOOD	It is computed as the average of the volumes of harvested wood (thou. m^3) in 1990-2017.	NIS, Own computation
Private forests/ PRIVATE_F %	It indicates the percentage of forest areas owned by private agents at county level (2014).	NIS, Own computation

*The negative values are modified in order to allow the integration of the specific data in the TOPSIS, without changing the mathematical relationships between the alternatives.

An important issue that has to be considered was the vagueness of the data involved, especially those concerning the cases of illegal forest cutting. According to Niță (2015), illegal forest exploitation may take three forms: "1- subsistence theft in undeveloped areas due to poverty and lack of jobs there; 2- mafia-type theft of wood processors in Romania; and 3- mafia-type theft of the superior unprocessed wood which is exported from Romania to other countries". These cases are identified by authorities and may be also reported by citizens. This means that the data may be incomplete, as it cannot be guaranteed that all the cases of illegal forest exploitation have been identified and/or sanctioned. The problem is addressed by introducing fuzzy logic elements by the use of FAHP, which will also increase the reliability of the results. Therefore, the weight of the illegal forest cutting cases is lower than it should have been in case the data was not provisional.

It may be possible that illegal forest cutting is more frequent in privately owned forests, due to the novelty of forestry activities that have to be performed by new owners and the monitoring necessities that are hard to meet by the authorities (Roman 2009, Schmithuesen and Hirsch 2010, Stancioiu et al. 2010, Abrudan 2012, Munteanu et al. 2016, Mihai et al. 2017, Popa et al. 2019). Starting in 1991, the forest land restitution process resulted in discrepancies regarding the number of private owners and the size of privately-owned forest areas. In this regard, Munteanu et al. (2016) state that the stability of forest ownership is associated with lower harvest rates. In 2014, there were more than 800,000 private forest owners with forest properties smaller than 10 ha. On the other hand, 75 % of the private forests, represented by large forest areas, were owned by less than 2,000 owners (World Bank 2014, Popa et al. 2019). This forest ownership distribution challenges the forestry laws, which have also inherited attributes from the communist period, are over prescriptive (Drăgoi et al. 2011, World Bank 2014, Nichiforel et al. 2018) and hard to implement (Popa et al. 2019). Because the veracity of the link between the privately-owned forest and the high incidence of illegal forest cutting is not definite, the factor concerning the private forest area was considered to be the least important.

In addition, the weight of the factor regarding the volume of harvested wood is low, as its values at county level are based on unsuited legislation (Popa et al. 2019), which also influences the context of the increase in the total forest cover of Romania. According to the Forest Act (2015), the quotas of the volume of harvested wood are set with respect to the annual possibility of exploitation. The volume of harvested wood may be allowed to exceed the annual possibility of exploitation by increasing the amount of wood products that result from natural destructive events (Forest Act 2015). In such cases, the harvesting quota for the next year should be reduced, but the quantity of the wood products obtained as a result of destructive events may also be artificially increased, forming a vicious circle of unsustainable practices. Wood products resulting from accidents or forest illegal cutting should also be subtracted from the established quota (Forest Act 2015). On the other hand, the number of accidental products may be artificially increased, which means that the reduction in the harvesting quota is not sustainable. These legislative glitches lead to unsuitable forest exploitation and allow for the thriving of corruption.

Therefore, the most relevant factors to the aforementioned goal are the ones regarding the actual changes in the forest areas at county level, implicitly the ones concerning forest loss and forest regeneration. Likewise, the changes in the forest provision offer an interesting perspective by concurrently considering the dynamics of the forest areas in relation to the population number.

The weights of the considered factors are obtained by using the following comparison matrix (Table 3). Firstly, the crisp numbers equivalents are integrated in AHP in order to determine the consistency of the judgements that will be used in FAHP. The resulting Consistency Ratio of 0.06 (< 0.1, as required) indicates that the judgements are valid and that they may be used as a basis for FAHP.

However, both the illegal cutting cases and harvested wood volume have weights under 10 %. Although of vital importance to the issue of hand, the illegal cutting cases (8.97 %) are provisional data with questionable accuracy. Also, the weight of the harvested wood volume (3.60 %) is computed by taking into consideration that the data are based on the quotas fixed per the ambiguous legislation. The FAHP indicates that the percentage of private forest areas was not of relevance to the assessment, as it was less important than all of the other factors. As previously mentioned, the assumption that illegal forest cutting is more frequent in private forest areas is still to be firmly confirmed. Thus, its weight was considered to be 0 % and it was not integrated in the TOPSIS.

Table 3. The comparison matrix of the considered factors

	CHANGE_FA %	F_LOSS	REG_AV	CHANGE_FP %	IC	WOOD	PRIVATE_F %
CHANGE_FA %	(1, 1, 1)	(1, 2, 3)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(4, 5, 6)
F_LOSS	(1/3,1/2,1)	(1, 1, 1)	(1, 2, 3)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(3, 4, 5)
REG_AV	(1/4,1/3,1/2)	(1/3,1/2,1)	(1, 1, 1)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)	(3, 4, 5)
CHANGE_FP %	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1, 1, 1)	(1, 2, 3)	(2, 3, 4)	(3, 4, 5)
IC	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1, 1, 1)	(1, 2, 3)	(3, 4, 5)
WOOD	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1, 1, 1)	(3, 4, 5)
PRIVATE_F %	(1/6,1/5,1/4)	(1/5,1/4,1/3)	(1/5,1/4,1/3)	(1/5,1/4,1/3)	(1/5,1/4,1/3)	(1/5,1/4,1/3)	(1, 1, 1)

Results

The results show the first three factors in the order of their importance are related to the forest loss and forest regeneration processes: forest area changing rate (27.90 %), forest loss (23.77 %) and forest regeneration works (21.29 %) (Figure 3). The differences regarding the computation of these factors explain the decision of not considering them equal. At the same time, such equality would result in significant discrepancies in relation to the weights of the other factors. The values of the three most important factors reflect a slight distinction, but the forest loss related factors were given higher weights because they cause the greatest threats to the forests. Furthermore, the regeneration process requires time and even after the new forest ecosystem develops, it remains more susceptible to natural destructive events. The next in the order of importance was the rate of change in the forest provision (14.44 %), which indicates the pressure exerted by population on the forest area.

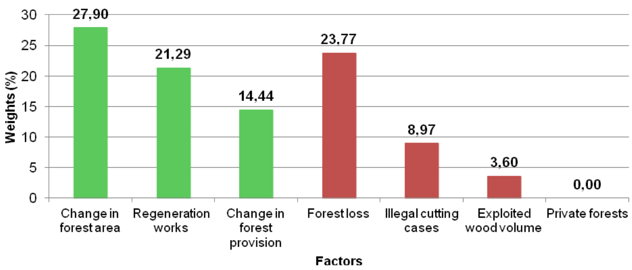

Figure 3. The weights of the considered factors

The forest area preservation level was defined using 5 classes with limits fixed as thresholds of the TOPSIS scores that illustrate the relative distance of each alternative to the positive and negative ideal solution. Results show 6 counties have a very low level of forest area preservation, 15 counties have a medium level of forest area preservation, and only 2 counties recorded a very high level of forest area preservation (Table 4, Figure 4).

The counties with the highest forest area preservation level were the following: Harghita, Brăila, Suceava, Caraş-Severin and Sibiu with scores ranging between 0.6935 to 0.4425 (Figure 4). These 5 counties recorded positive changes in the forest provision and the average values of the forest regeneration between 1990 and 2017 exceeded the average national value (316.39 ha). All these counties show positive changes in forest area in 2017 compared to 1990, except Suceava County (Figure 4).

Table 4. The classes of forest area preservation level based on the output of TOPSIS

Forest area preservation level	Class limits	No. of counties
Very low	< 0.25	6
Low	0.25-0.30	11
Medium	0.30-0.40	15
High	0.40-0.65	7
Very high	> 0.65	2

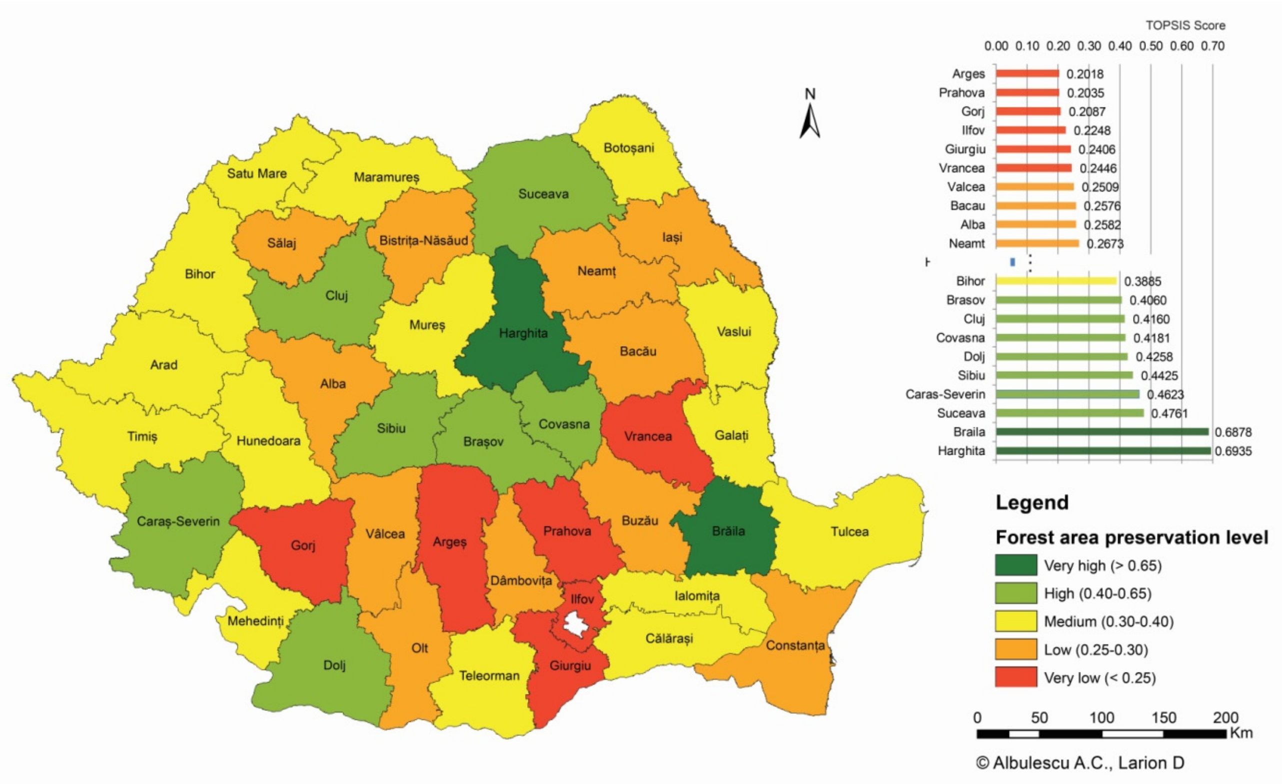

Figure 4. The forest area preservation level in the counties of Romania

The counties with the lowest forest area preservation levels were the following: Argeş, Prahova, Gorj, Ilfov, Giurgiu and Vrancea with scores ranging between 0.2446 to 0.2018. All of them were characterised by medium to high values of the forest loss and negative rates of change in the forest area. The changes in the forest provision are positive for all of them, except Ilfov County in which a significant population growth in recent years due to its proximity to Bucharest has been registered.

Considering Figures 1 and 4, it appears that the counties with the most extended forest cover, namely Suceava and Caraş-Severin, have a high forest area preservation level, while the counties with less than 25,000 ha of forest have a very low (Ilfov County) or medium (Ialomiţa, Călăraşi) forest area preservation level. However, a definite link between the size of the forest cover and the level of forest area preservation cannot be established, as there are counties with very low levels of forest area preservation and a medium extension of the forest cover (Argeş, Gorj, Vrancea and Prahova) or with small sized forests (Giurgiu). In addition, the counties with a high level of forest area preservation may have a medium-sized forest cover (Braşov, Sibiu, Covasna and Cluj) or less than 100,000 ha of forests (Dolj).

Discussion

Forest preservation or conservation studies in Romania focus on biodiversity related aspects specific to certain areas/regions (Borlea et al. 2006, Feurdean and Willis 2008, Feurdean 2010) or on forest area change in certain locations (Munteanu et al. 2016, Mihai et al. 2017). As this study is the first one to analyse forest preservation in Romania at county level using MCDM methods, the results cannot be compared with other findings of this type.

However, by comparing the aforementioned findings with the Greenpeace Romania Reports (2009-2017) on illegal forest cutting, some interesting inferences may be deduced. Some of the counties with the lowest forest area preservation level (i.e. Argeş, Prahova, Gorj and Vrancea) exceed 1,000 illegal cutting cases as average for the 2009-2017 period, thus ranking them in top 7 counties regarding this predicament (Figures 1, 4). On the contrary, other two counties with low forest area preservation level (Ilfov and Giurgiu) registered the lowest values of illegal cutting cases. The average number of illegal cutting cases (2009-2017) is lower than the national average of 623.02 in some counties with very high or high forest area preservation, like Brăila and Caraş-Severin counties, and higher than this value for the rest of the counties in this class of high forest area preservation (Figures 1, 4). This may suggest that the forest loss at county level is not only caused by illegal forest cutting, but the provisional character of data regarding this outlaw practice precludes any certain conclusions.

A previous study focusing on 3 protected areas, in Maramureş, Suceava, Bistiţa-Năsăud, Mureş and Harghita counties, identified high levels of forest disturbances (Knorn et al. 2012) that are associated with medium or low forest area preservation levels in our study (for Maramureş, Mureş, Bistiţa-Năsăud). In spite of this fact, Suceava and Harghita counties are characterised by high and very high forest area preservation. Nonetheless, it should be noted that the protected areas cover only a small-sized territory of Harghita, Suceava, Bistriţa-Năsăud and Mureş counties.

A study on forest disturbances in 2000-2013 as compared to 1912-1922 shows that forest harvesting in this century, which did not necessarily lead to forest loss, was concentrated in counties with medium (Mureş, Ialomiţa, Călăraşi) or low (Bistiţa-Năsăud, Bacău, Neamţ) forest area preservation levels, as well as in some counties with high forest area preservation levels (Suceava, Cluj, Covasna). In addition, the low elevation counties of Ilfov, Constanţa and Olt, where historical forest harvesting was concentrated (Munteanu et al. 2016) recorded very low to low forest area preservation level.

MCDM methods have only recently emerged in Romanian scientific literature and have been mainly integrated in risk assessments. This paper represents one of the few applications of MCDM methods in the field of forestry research in Romania. This modern approach combines fuzzy and classical MCDM methods and provides a salient hierarchical framework that addresses the issue of data fuzziness and allows for evaluation at county-size scale. Our previous work includes an assessment of the forest loss magnitude in 4 counties (Alba, Gorj, Maramureş and Suceava) via AHP (Albulescu et al. 2017).

A recent application of a MCDM method in Romanian forest management has been developed by Drăgoi (2018) to establish if private non-industrial forests from Suceava County should be joined into a single management unit. In this study, the Analytic Network Process (ANP) is used to create a framework that includes benefits, opportunities, costs and risks defined from social, economic and ecological perspectives (Drăgoi 2018). Another application of the AHP in this field consists of a benefit, cost and risk analysis on extending the forest road network in the Crasna Valley (Drăgoi et al. 2015).

On the other hand, the applications of MCDM in the fields related to forest management, such as forest planning (Mendoza and Sprouse 1989, Kangas 1992, Kangas and Kuusipalo 1993, Kangas 1994), ecological evaluation (Anselin et al. 1989) or evaluation of reforestation alternatives (Kangas 1993) are not new in international scientific literature. It appears that the Scandinavian scientific literature on this subject is particularly developed, as observed in the review of this type of methods with special reference to forest management and planning written by Ananda and Herath (2009). The article reviews over 60 studies classified by method, country of origin, number and type of considered criteria, and the evaluated options.

However, the theoretical developments of MCDMs exceed the empirical applications as there is a reluctance to accept the MCDM methods as tools that can be used in land use problems analysis (Ananda and Herath 2009; Romero and Rehman 1987). The improvement of the accuracy and the adaptation of this type of methods to the particularities of the various research subfields in which they are integrated should ensure an increase in both scientific value and applicability.

This study is one of the first forestry-related integration of MCDM methods in Romania, focusing on forest preservation issues considering the 41 counties. Such knowledge is a prerequisite for salient spatial planning strategies and forest loss mitigation plans. Therefore, one of its strengths consists in partially filling the gaps concerning forest loss at county level. The approach may be developed by considering new factors, like the ones regarding the funds that are allocated by each administrative unit for forest regeneration works and factors referring to the mentality of the population concerning the value of the forests and their exploitation.

Conclusions

The artificial increase of the forest cover in Romania offers misleading information about the exploitation and preservation of forest areas, also masking the possibility that forest loss at county level may extend at national scale. The context of this issue includes an outdated, ambiguous legislation and an increase in illegal forest cutting cases, shadowed by a high level of corruption. The matter of illegal cutting is sensitive due to the fact that the consistent efforts of the authorities and of the civil society address the problem when significant areas of forest have already been cut and it is too late to prevent it. Nevertheless, the actions that aim to legally punish and report such cases are important in the long term.

Argeş, Prahova and Gorj counties have the lowest level of forest area preservation and also stand out as being affected by massive illegal forest cutting, while Harghita, Brăila and Suceava counties are placed at the other end of the preservation spectrum. Therefore, the implementation of forest loss mitigation strategies should start with the first three aforementioned counties and proceed to the ones with high and medium levels of forest area preservation levels.

The results show the forest area preservation at administrative unit level, identifying counties that are the most endangered in terms of forest loss and need urgent amelioration-oriented interventions. Thus, this study may serve as a practical tool in the endeavour to mitigate forest loss and to achieve sustainable forest exploitation. It should be emphasised that some of the data used in this assessment were uncertain and/or incomplete, problem which is addressed by weighing the specific factors via a fuzzy MCDM method.

The goal of achieving sustainable forest area preservation levels both at regional and local scale becomes even more relevant in the current situation of climatic changes. The prerequisites of this goal consist in implementing sustainable forest management programmes using proper legislative, institutional and technological instruments, as well as shifting the mentality of the population from focusing on the immediate economic gain that can be obtained through forest exploitation to recognising the far-reaching benefits of forest preservation.

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