Decision making tree for determining risks in forest management

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ABSTRACT

Forests have traditionally been used for timber production. However, society's expectations have significantly changed, and other forest functions, such as ecological and social functions, have become more important. Increasing of uncertainty, diverse societal interests, and the abound data have led to the use of multi-criteria models to support decision-making in forestry. The goal of this paper is to develop the decision-making tree, with the help of which we identify the risks that have the greatest impact on forest management. A review of literature of the most frequently used risks in forest management was made. Then the decision-making tree was constructed. The criteria represent different forest functions (economic, social and ecological), sub-criteria are different risks that may affect the selected functions. Decision makers will evaluate the model. The model will be evaluated using Weighted Influence Non-linear Gauge System of finite sum of influences (FSI WINGS) and fuzzy Best – Worst Method (BWM).

KEYWORDS

Decision making, forest management, risks, weighted influence non-linear gauge system of finite sum of influences, fuzzy best – worst method

1 INTRODUCTION

Traditionally, forests have been used and managed mainly for timber production. In recent decades, societal expectations of forests have changed significantly. In addition to the traditional production function, the other (ecological, economic, social and cultural) forest function have become important (Eggers et al., 2019; Standovár et al., 2016).

Increasing uncertainties due to climate change and increasing amount of information have led to a growing interest in decision support systems for forest management (Vacik and Lexer, 2001). Multi-criteria decision making (MCDM) is the collective term for mathematical methods used to solve decision problems with multiple, usually conflicting, goals (Eggers et al., 2019).

Due to the forest management sustainability assessment process is a complex task, mainly because it involves integration of multiple environmental, socio-economic and institutional impacts at different spatial scales of different forest management policies, which are considered for implementation at any forest location, nowadays, the MCDM methods in forestry is significantly increasing (Kazana et al., 2020; Ortiz et al., 2019).

Risks play a significant role in forest management. Understanding their importance is crucial for effective and sustainable forest management. By identifying and assessing these risks, forest managers can implement appropriate measures to mitigate or prevent their negative effects (Pasalodos-Tato et al., 2013).

This paper is part of a work in progress. The objective of the first part of the paper is to conduct a literature review and select the most commonly used forest functions and the most threatening risks in forestry. Based on this research, we develop a multi-criteria model to support forest management and to identify which risks most threaten forest management.

2 METHODS

2.1 Literature review

The first step in building the decision tree is to review the risks. To find out what risks are involved in forest management, we conducted a literature review. The most frequently highlighted risks are listed in Table 1.

Table 1. Most common risks in forest management in the literature

Risks	References
Natural disasters (windthrow, drought)	(Akay et al., 2018; Kazana et al., 2020)
Illegal logging	(Akay et al., 2018; Kazana et al., 2020)
Hunting	(Akay et al., 2018; Kazana et al., 2020)
Diseases	(Lieffers et al., 2020; Marques et al., 2021)
Invasive species	(Lieffers et al., 2020)
Pests	(Kazana et al., 2020; Lieffers et al., 2020; Marques et al., 2021)
Fires	(Kazana et al., 2020; Lieffers et al., 2020; Marques et al., 2021; Sadono et al., 2019)
Biodiversity	(Kazana et al., 2020; Lakicevic et al., 2014; Marques et al., 2021; Sadono et al., 2019)
Erosion	(Kazana et al., 2020; Marques et al., 2021; Sadono et al., 2019)
Risks	**References**
Timber price	(Marques et al., 2021; Sadono et al., 2019; Zhang et al., 2020)
Number of employees	(Sadono et al., 2019; Sironen et al., 2020; Zhang et al., 2020)

Water function (water supply)	(Kazana et al., 2020; Zhang et al., 2020)
Owner activities	(Sironen et al., 2020),
Age of plantations	(Sironen et al., 2020),
Timber stock	(Kazana et al., 2020; Sironen et al., 2020)
Accessibility of forest areas to visitors (recreation)	(Kazana et al., 2020; Lakicevic and Srdjevic, 2022; Marques et al., 2021; Sironen et al., 2020)
Climate change	(Lakicevic et al., 2014; Lakicevic and Srdjevic, 2022)

2.2 Multi-criteria decision-making methods

Multicriteria decision-making (MCDM) is the collective term for mathematical methods for solving decision problems with multiple, usually, conflicting goals (Eggers et al., 2019). There are many different decision methods, such as AHP (Analytic Hierarchical Process), TOPSIS (Technique for Order Performance by Similarity to Ideal Solutions), DEMATEL (Decision Making Trial and Evaluation Laboratory) method and others (Gabus and Fontela, 1972). Two methods of them are also WINGS (Weighted Influence Non-linear Gauge System) and BWM (Best – worst method). On the first level criteria – forest function will be evaluated by FSI WINGS method, while sub-criterion - risks will be evaluated by fuzzy BWM. FSI WINGS method was chosen because it takes into account the influences between the factors and also the strengths of the factors. Fuzzy BWM was chosen because it is relatively new and easier to use than AHP method because it requires fewer pairwise comparisons.

2.2.1 Weighted Influence Non-linear Gauge System

The Weighted Influence Non-linear Gauge System (WINGS) method has been derived from DEMATEL methods and can be used as a structural model for analysis of intertwined factors and causal relations between them. This method includes the influences of the elements in the system and also the strength of each elements (Michnik, 2013). Some authors used fuzzy evaluations to include the uncertainty into the WINGS method. Most commonly used are triangular fuzzy numbers (Tavana et al., 2021). However sometimes the convergence problem can occur and fuzzy WINGS method can not be used. Authors proposed new method FSI WINGS, that instead of an infinite sum, a finite sum of terms is used (Šmidovnik, 2022).

2.2.2 Best – worst method

One of the multi-criteria decision-making methods is Best - worst method (BWM). This method is based on pairwise comparisons. Decision makers select the best (most important) elements of the systems and the worst (least important) elements of the system. Then pairwise comparisons are conducted between each of those two criteria (best and worst criterion) and all the others criterion (Rezaei, 2015). Also, BWM can use triangular fuzzy numbers for evaluations.

2.3 Selection of decision makers

We are interested in the opinion of the different groups of decision makers. This way, we can compare the results between the groups. We selected that our model will be evaluated by four different groups of decision makers - experts on forest management, visitors of forest (recreationists), conservationists and foresters. Each group will consist of 3 to 6 decision makers.

The decision makers are selected with a non-probability judgmental sampling method, where the representors are selected qualitatively, their number is not important by this method (Dobšinská et al., 2020).

3 RESULTS

3.1 Multi-criteria model for consider risk in forest management

We constructed a multi-criteria model of three levels (Figure 1), whose objective is to select the most important risks for forest management. The second level consist of criteria that represent different forest functions. Selected forest functions are ecological, social, and economic functions (Kazana et al., 2020; Sironen et al., 2020; Zhang et al., 2020). The sub-criteria represent the risks in forest management. To find out which risks are most often mentioned in the literature, we made an extensive literature review (Table 1). Then, we reviewed the risks with the experts and selected those that are most relevant in our region. The sub-criteria of production function are illegal logging, timber price and natural disasters. Sub-criteria of social function are social security, recreation, owner's activity, forest pollution. Sub-criteria of ecological function are climate change, insects, non-native species and biodiversity loss.

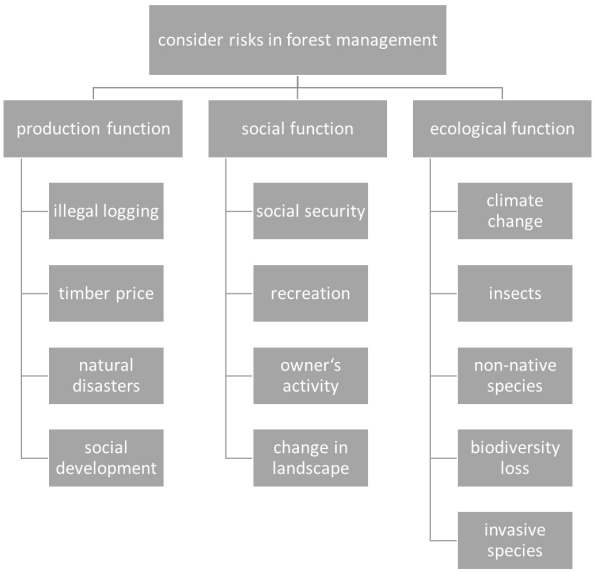

Figure 1. Decision making model for consider risk in forest management

This decision-making model for consider risk in forest management (Figure 1) can be used in generally for a larger area or for a specific area. Also, we can adjust the selection of decision makers or add criteria depending on the selected area.

3.2 Future Work

When the decision-making model was constructed and method to evaluate them was selected, we prepared the questionnaire to evaluate the model. FSI WINGS will be used to evaluate the criteria and fuzzy BWM will be used to evaluated the risks. This questionnaire will be sent to the chosen decision makers. Based on decision makers assessments, we will determine which risk represents the greatest threat to forest management.

4 CONCLUSION

Traditionally, forest was used for timber production, but nowadays society's expectations have changed. The non-productive functions of the forest have also become important. In addition, forest management is also complicated by risks.

The multi-criteria model to consider risks in forest management was created. Three forest functions (production, social, and ecological) are selected as criteria, and their sub-criteria are the risks that arise. Results will show out which risk is most and which is the least threatening for forest management. In the future, the scenarios for forest management can be added.

5 REFERENCES

// Akay A.O., Demir M., Akgul M. 2018. Assessment of risk factors in forest road design and construction activities with fuzzy analytic hierarchy process approach in Turkey. Environmental Monitoring and Assessment, 190, 9, 561. 10.1007/s10661-018-6948-0: 10.1007/s10661-018-6948-0.

// Dobšinská Z., Živojinović I., Nedeljković J., Petrović N., Jarský V., Oliva J., Šálka J., Sarvašová Z., Weiss G. 2020. Actor power in the restitution processes of forests in three European countries in transition. Forest Policy and Economics, 113. 10.1016/j.forpol.2020.102090: 10.1016/j.forpol.2020.102090.

// Eggers J., Holmgren S., Nordström E.-M., Lämås T., Lind T., Öhman K. 2019. Balancing different forest values: Evaluation of forest management scenarios in a multi-criteria decision analysis framework. Forest Policy and Economics, 103, 55-69, 10.1016/j.forpol.2017.07.002: 10.1016/j.forpol.2017.07.002.

// Gabus A., Fontela E. 1972. World Problems, An Invitation to Further Thought within the Framework of DEMATEL.

// Kazana V., Kazaklis A., Raptis D., Stamatiou C. 2020. A combined multi-criteria approach to assess forest management sustainability: an application to the forests of Eastern Macedonia & Thrace Region in Greece. Annals of Operations Research, 294, 1-2: 321-343. 10.1007/s10479-020-03751-0: 10.1007/s10479-020-03751-0.

// Lakicevic M., Srdjevic Z., Srdjevic B., Zlatic M. 2014. Decision making in urban forestry by using approval voting and multicriteria approval method (case study: Zvezdarska forest, Belgrade, Serbia). Urban Forestry & Urban Greening, 13, 1, 114-120. 10.1016/j.ufug.2013.11.001: 10.1016/j.ufug.2013.11.001.

// Lakicevic M., Srdjevic B. 2022. An Approach to Developing the Multicriteria Optimal Forest Management Plan: The "Fruska gora" National Park Case Study. Land, 11, 10. 10.3390/land11101671: 10.3390/land11101671.

// Lieffers V.J., Pinno B.D., Beverly J.L., Thomas B.R., Nock C. 2020. Reforestation policy has constrained options for managing risks on public forests. Canadian Journal of Forest Research, 50, 9: 855-861. 10.1139/cjfr-2019-0422: 10.1139/cjfr-2019-0422.

// Marques M., Reynolds K.M., Marto M., Lakicevic M., Caldas C., Murphy P.J., Borges J.G. 2021. Multicriteria Decision Analysis and Group Decision-Making to Select Stand-Level Forest Management Models and Support Landscape-Level Collaborative Planning. Forests, 12, 4. 10.3390/f12040399: 10.3390/f12040399.

// Michnik J. 2013. Weighted Influence Non-linear Gauge System (WINGS) – An analysis method for the systems of interrelated components. European Journal of Operational Research, 228, 3: 536-544. 10.1016/j.ejor.2013.02.007: 10.1016/j.ejor.2013.02.007.

// Ortiz U., González P., Diaz B. 2019. Decision-Making in Forestry: A Review of the Hybridisation of Multiple Criteria and Group Decision-Making Methods. Forests, 10, 5. 10.3390/f10050375: 10.3390/f10050375.

// Pasalodos-Tato M., Mäkinen A., Garcia-Gonzalo J., Borges J.G., Lämås T., Eriksson L.O. 2013. Review. Assessing uncertainty and risk in forest planning and decision support systems: review of classical methods and introduction of new approaches. Forest Systems, 22, 2. 10.5424/fs/2013222-03063: 10.5424/fs/2013222-03063.

// Rezaei J. 2015. Best-worst multi-criteria decision-making method. Omega, 53: 49-57. 10.1016/j.omega.2014.11.009: 10.1016/j.omega.2014.11.009.

// Sadono R., Soeprijadi D., Nikimah S.F., Wariabuana P.Y.A.P. 2019. Determining the best agroforestry system using multicriteria analysis in Banyumas Forest Management Unit. IOP Conference Series: Earth and Environmental Science, 449.

// Sironen S., Primmer E., Leskinen P., Similä J., Punttila P. 2020. Context sensitive policy instruments: A multi-criteria decision analysis for safeguarding forest habitats in Southwestern Finland. Land Use Policy, 92. 10.1016/j.landusepol.2019.104460: 10.1016/j.landusepol.2019.104460.

// Standovár T., Szmorad F., Kovács B., Kelemen K., Plattner M., Roth T., Pataki Z. 2016. A novel forest state assessment methodology to support conservation and forest management planning. Community Ecology, 17, 2: 167-177. 10.1556/168.2016.17.2.5: 10.1556/168.2016.17.2.5.

// Šmidovnik T. 2022. New WINGS approach - WINGS of finite sum of influences. Engineering management, 8, 1: 36-47.

// Tavana M., Mousavi H., Khalili Nasr A., Mina H. 2021. A fuzzy weighted influence non-linear gauge system with application to advanced technology assessment at NASA. Expert Systems with Applications, 182. 10.1016/j.eswa.2021.115274: 10.1016/j.eswa.2021.115274.

// Vacik H., Lexer M.J. 2001. Application of a spatial decision support system in managing the protection forests of Vienna for sustained yield of water resources. Forest Ecology and Management, 143, 1-3: 65-76. 10.1016/s0378-1127(00)00506-5: 10.1016/s0378-1127(00)00506-5.

// Zhang T., Lan J., Yu J., Liu Z., Yao S. 2020. Assessment of forest restoration projects in different regions using multicriteria decision analysis methods. Journal of Forest Research, 25, 1: 12-20. 10.1080/13416979.2019.1704360: 10.1080/13416979.2019.1704360.