IMPACT OF THE ACTUAL STRUCTURE AND MANAGEMENT ON THE FUTURE DEVELOPMENT AND SUSTAINABLE MANAGEMENT OF THE PEDUNCULATE OAK FORESTS IN EASTERN CROATIA

Krunoslav Teslak, Jura Čavlović, Karlo Beljan, Dario Tomašević*

Faculty of Forestry, University of Zagreb, Croatia

**kteslak@sumfak.hr*

Introduction

Pedunculate oak forests are the most common forest type in eastern Croatian with a 50% share of total pedunculate oak forests and area of 129 thousand hectares [1]. Therefore, pedunculate oak forests in eastern Croatia present a significant and valuable natural resource whose sustainable exploitation should be based on appropriate and sustainable forest planning and management. The area represents a favourable spatial framework for considering strategic and long-term management planning of pedunculate oak forests. The main starting points of forest management planning are: existing age structure and forest development directing; structural and development stand characteristics; forest regeneration intensity and dynamics.

The age of stand, that is, its relation to theoretical age is crucial for future management planning [2,3]. As oppose to the balanced forest structure and stand, in poorer conditions the relation and range of the stands' felling age can vary considerably in rotation period. However, the balance is required between the stands with early and postponed regeneration [4]. Therefore, the deterioration level of the stand structure and the value of wood stock are becoming more important criteria for planning the regeneration fellings [5, 6]. The issue of planning suitable regeneration dynamics and selecting the stands for regeneration is especially highlighted in low-land forest management, primarily pedunculate oak forests, where drying of trees and parts of the stands presents a huge ecological and economic problem [7,8]. The presumption is to use the approach of priority regeneration of the (understocked stands) more deteriorated structure independently of their age, at the same time regenerating the deteriorated habitat by oak trees dieback [5,9,10].

Using SIMPLAG computer programme, the study's aim is to conduct a projection of the structure development on the level of each 6538 stands of the pedunculate oak management class in eastern Croatia according to several different scenarios of spatiotemporal dynamics of forest regeneration; and to analyse the development of the forest age structure and achieved potential revenues from the value of wood. Furthermore, the aim is to discuss and evaluate the applied management scenarios on the basis of several criteria and suggest optimal scenario on the basis of which the evaluated forest could be subject to long-term sustainable management with improving the existing state and reaching potential productiveness.

Materials and Methods

This study covers the area of the pedunculate oak management class in eastern Croatia, that is, the area divided in five Forest Administrations on the basis of forest and management criteria: Osijek, Vinkovci, Našice, Požega and Nova Gradiška. In total forest area of eastern Croatia (357.986 ha), the forests structurally classified as pedunculate oak forests cover the area of 103.440 ha or 29%. The age structure of pedunculate oak forests of eastern Croatia has features similar to the age structure of all pedunculate forests in Croatia. Concerning the regional spatial management level (a total of 79 management units) which includes the discussed age structure, considerable deviations from theoretical values exist. The characteristics of the age structure are: excessive 100 years old stand coverings (46,0%), small coverings of young (7,5%) and middle-aged stands (19,4%), but also mature stands (7,4%), with intensive regeneration over the past 20 years (19,7%).

In total, 6538 stands of the pedunculate oak management class on the research area have been selected based on the inventory of the Croatian Forest Fund (database of Croatian Forests Ltd.). On the basis of data on the related management unit (year of measurement, age of stand, area, number of trees, basal area, volume and volume increment per hectare and per tree species) a database was created for each subcompartment, and logic analysis and control was performed. SIMPLAG application for simulating the development of the pedunculate oak forest was used for projecting the development of the existing stands up to the time of their regeneration and determining the main felling as well as the development of the newly regenerated stands [10]. The application simulates various spatiotemporal regeneration dynamics, that is, predictions according to space and intensity of different 10 year main felling, which defines specific management scenarios. Different management approaches are defined according to four management scenarios:

- Scenario 1 – Intensity of the main fellings are continuously applied on 60% area of theoretical 20-year old age class. The evaluation includes stands that were determined to be over 100 years old in the moment the felling was classified.
- Scenario 2 – During the projection period, the main fellings are continuously applied on the basis of stands over 130 years old.
- Scenario 3 – Dynamic area of the main fellings are determined according to the area of stands determined to be over 100 years old
- Scenario 4 - Dynamic area cut of the main fellings is determined according to the area of stands determined to be over 120 years old in the moment of determining the main revenue cut.

The deterioration level of the stand structure was the selection criteria chosen for scenarios 1, 3 and 4. The cut volume of the main fellings for all scenarios results from the planned main felling area and total area of the included stands which makes the determined scenarios significantly different one from another.

Besides projecting the development model of the stands, on the basis of the embedded models of assortment structure and wood price, SIMPLAG also calculates values of achieved cuts which enables cross-analysis and evaluation of each scenario's applicability [11]. The criteria of the scenario management valuation and the approach for determining the regeneration stands are based on the relation between the development elements obtained

from real forests and theoretical forests. The elements of the theoretical forest are determined on the basis of appropriate equations for defining a model of theoretical regulated even-aged forest [12].

The valuation of total achieved volume cuts and revenues is based on achieved total, that is, average amounts and compared individual indicators that deviated from the defined theoretical indicators [2]. Comprehensive evaluation and the scenarios' success in achieving the management goals were conducted according to the method of mutual pair comparison [13]. Structural and economic indicators of the applicability of each management scenario were compared as well as the volume cut sustainability during a certain projection period. Furthermore, the successfulness of determining a theoretical age structure, forest eco-stability, balances and short-term and also long-term management sustainability were analysed according to the determined scenarios. The calculation of the required variables, database formation and graphic overviews were performed in *Microsoft Excel 2010*. SIMPLAG application was used for forest development projections [10].

Results and Discussion

By analysing the development of an even-aged forest on the basis of seven indicators and their deviation from the theoretical ones (based on the results presented in Table 1), the management approach based on Scenario 1 stands out since 128% area of the pedunculate oak forests would be regenerated using this scenario's intensive regeneration approach. This would result in reducing the stands' average age and the stands' regeneration age; it would also reduce growing forest stock, with increasing the main regeneration cut by 15-16.5 million m^3, decreasing the intermediate cut (5-5.8 million m^3) and achieving value of total fellings which would be HRK1 billion higher in relation to other management approaches. From the point of view of revenues sustainability, Scenario 3 shows the smallest deviations of forest status and management indicators in relation to the theoretical criteria, which is most preferable solution.

Table 1. Management approach (scenarios) valuation by comparison of total achieved amounts over the projection period and deviations over the projection period for the appropriate management criteria. PDS – average stand age, PSEGD – average stand regeneration age, $DZ_{\check{S}}$ – growing forest stock (average amount), UPO – total regenerated forest area, EG – regeneration cuts, EM – intermediate cuts, EUK – total fellings, BEGP – gross value of regeneration fellings, BEMP – gross value of intermediate fellings, BUKP – value of total fellings.

Criteria		Scenario							
		1		2		3		4	
		∑	I_{OPS}	∑	I_{OPS}	∑	I_{OPS}	∑	I_{OPS}
PDS	*year*	63	0.1583	68	0.1137	72	0.039*	70	0.0762
PDSEG	*year*	123	0.1291	135	0.033*	134	0.1369	135	0.0843
$DZ_{\check{S}}$	10^6	33.81	0.1126	36.95	0.1369	37.35	0.110*	37.31	0.1518
UPO	10^3	132.94	0.1995	107.14	0.4621	114.29	0.157*	108,79	0.3673
EG	10^6	75.02	0.1927	58.52	0.4451	60.41	0.178*	58.73	0.3187
EM	10^6	70.46	0.2127	77.30	0.2291	76.03	0.178*	78,43	0.2320
EUK	10^6	145.48	0.1448	135.82	0.2478	136.43	0.170*	137.16	0.1877
BEGP	10^9	30.74	0.289*	26.46	0.4512	25.56	0.3868	25.65	0.3805
BEMP	10^9	16.41	0.3313	19.19	0.2855	20.17	0.239*	20.23	0.2907
BUKP	10^9	47.14	0.292*	45.65	0.3494	45.73	0.3120	45.88	0.3086

* scenario with smallest criteria deviations from the theoretical model

Besides considering the development of the even-aged forests' main features per each scenario and their mutual comparison, their total valuation and selection of the most favourable one for applying in real forests is what the end-user considers important. The valuation has to encompass all long-term advantages and disadvantages of each scenario [14]. Furthermore, it is important to analyse is it possible and in which period it is possible to achieve optimal age structure, optimal forest spatial structure, forest eco-stability and management balance during the projected period.

Quantification of the acceptability of each management scenario, that is whether their application is justified, was performed for six criteria (Table 3) which encompass the most important forest management goals (Table 2). Each scenario was rated according to the criteria and the result was a rank list of scenarios per each criteria. These results point to the economic superiority of Scenario 4 and relatively most acceptable age structure movements through the projected period of Scenario 3 (Table 2).

Table 2. Evaluation matrixes for selected feasibility criteria of applying the determined management scenarios (example for two criteria).

Development of forest age structure through the projected period	1	2	3	4	Total	Transformed	Relative
1		5	-4	6	7	**37**	46.84
2	-5		-7	-3	-15	**15**	18.99
3	4	7		4	15	**45**	56.96
4	-6	3	-4		-7	**23**	29.11
Total	-7	15	-15	7	0	83	100.00

Economic profit	1	2	3	4	Total	Transformed	Relative
1		5	4	3	12	**42**	53.16
2	-5		-2	-1	-8	**22**	27.85
3	-4	2		-2	-4	**26**	32.91
4	-3	1	2		0	**30**	37.97
Total	-12	8	4	0	0	78	100.00

On the basis of the achieved points for each scenario, it is possible to perform the final acceptability evaluation of each scenario and form the rank list according to acceptability of each scenario which would be based on all important requirements of contemporary forest management planning. On the basis of total points, Scenario 3 stands out as the most acceptable since its implementation during the future period of one rotation period could achieve the set management goals or come as close as possible, uniting the advantages in economic and environmental sense (Table 3). Scenario 1 is applicable only in the circumstances of extremely excessive numbers of mature stands, and only for a short-term during several economic half-period. Generally speaking, static methods for determining the main fellings are not applicable in the long-term sense, except in theory, since they do not correspond to multi-criteria and overall planning approach and management implementation.

Table 3. Total table of determined points per each management scenario.

Evaluation criteria of management scenarios	Management scenario			
	1	2	3	4
	points*	points *	points *	points *
Level of establishing even-aged structure at the end of the projected period	27	16	37	26
Development of forest age structure during the projected period	37	15	45	23
Forest spatial structure (area and spatial layout of the stands)	22	44	28	26
Forest eco-stability during the projected period	29	26	40	29
Revenues sustainability and management balance	30	18	50	22
Economic profit	42	22	26	30
Total	187	141	**226**	156

*points per each scenario relate to transformed values of pair comparison of individual scenarios from Table 3

Concerning the highly considered theoretical area (over 50% surface of the pedunculate oak management class in Croatia) and the starting forest age structure, the scenario based on 50% area of the theoretical area of a 20-year old age class and main fellings formation based on the deterioration degree of the stands' structure requires further research. It is assumed that it would correspond to the analysed Scenario 3 based on the projected results or it would possibly exceed it with somewhat more balanced revenues.

The fact is that long-term projections can be very helpful when selecting management models or reducing mistakes which are long-term in forestry and thus very expensive. On the other hand, in the circumstances of intensive and hardly predictable changes in the habitat, long-term projections of forest development are very ungrateful. In this study the projections are burdened with several key assumptions: unconditional successful regeneration, absolute realisation of management regulations and structural development of newly regenerated stands equal to theoretical model. In this sense, future research should include risk assessment and feasibility of individual processes. Including spatial criteria (over-felling, surface cut layout in space, possible stand fluctuation between management classes and changes in stand surfaces) could provide options for improving long-term projections of forest planning and management.

Conclusions

Forest habitats of the pedunculate oak in eastern Croatia with an area of 130.000 ha, that is, over one third forests in Slavonia and around a half of all pedunculate forests in the Republic of Croatia, are extremely valuable and important natural resource. Based on the structure of

forests and stands, there are considerable options and requirements for gradual improvement of the existing state and achievement of potential productivity in the sense of forming an even-aged and spatial forest structure; shaping and quality promotion of the existing and newly regenerated stands as well as increasing the value of the fellings. Since the negative influences on forest eco-systems are not easily predicted, the goal of achieving the mentioned management criteria and potential 10 year gross revenue of around HRK4.4 billion could be supported by the management approach according to scena rio 3. According to given scenario cutting intensity is based on stand area dynamics of stands older than 100 years, as well as by objective criteria (economic, structural and habitat features of the stands) for selecting the stands for regeneration. Such approach has proven to be the most acceptable for sustainable management in the long-term and short-term sense.

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