Spatial aspects of biodiversity as a part of harvest scheduling decision process

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ABSTRACT

Over the last decade, influence of non-wood productive functions, such as environmental, have been increasingly expanding. We can expect that the impact of these functions will continue to grow due to mitigation of climate change impact. As a result, foresters have to seek tools for solving complex ecosystem management problems that include social, environmental and timber-productive functions. The real forest management problems are multi-objective, it means they include more than one objective, and a lot of different restrictions and constraints as well, such as configuration of patches, their size and distribution, shape, adjacency or green-up delay, connectivity, proximity or core area and many others. These problems can be solved by special exact mathematical methods such as multi-objective programming and by tools of geographic information systems (GIS). The use of multi-objective programming in forestry brings many risks. Determination of objective weights can be one of the many problems. Other problem is that each objective takes vastly different values in real environmental problems in most cases. This work presents possible solution on the example of spatial harvest scheduling with regards to the biodiversity aspects.

INTRODUCTION

Forest ecosystems perform multiple functions. Traditionally, forests have a threefold value: economic, social and environmental. In the case of forest management used only for production, it is not possible to comply with all functions of forest ecosystems. Multiple-use forestry is based on the idea that forests can provide value through other functions as well. Modern forestry has to find and field test new harvest scheduling methods, which can reflect new management and nature conditions. Many different models for harvest scheduling have been developed, and many different techniques for their solving have been used.

Many multiple-use forestry objectives, such as biodiversity, are affected by spatial structure, which can be included in harvest scheduling models via spatial constraints. For this reason, these types of models are part of the endogenous approach. The optimization algorithms of the endogenous approach include spatial information and a very large number of spatial constraints. Spatial harvest scheduling models and methods for their solving are developed and tested today.

Many birds and mammal species may benefit from spatial homogeneity within stands. Many animal species need young forest stands for nesting but old forest for migration as well. The edge-effect can be created by human activities, such as clear cuts or the creation of a core area because of the buffer zone of the core area. The main idea is to minimize the edge-effect. This means creating the smallest outside perimeter of the continuous reserve area in comparison with its area. The formulation of the outside perimeter is inspired from the model by.

The objectives of the defined harvest scheduling problem can be reached by means of mathematical programming. The nature of these objectives itself makes them mutually contradictory. A compromise solution to this multi-objective programming problem needs to be found. The importance is expressed by setting up weights for each objective function. The weights can be finally determined using Saaty's method.

MATERIAL AND METHODS

Real Forest Management Area (FMA) was selected for analysing. This FMA is close to Protected Landscape Area and several Natural Park.

The even-flow constraints and the adjacency constraints are important parts of model. The analytical algorithm for deriving adjacency constraints is used. It was used the ArcGIS tool (OPTIMAL) for editing harvest units and solving which is being developed at the Department of Forest Management of FFWS CULS in Prague.

The base aspect of biodiversity function of forest ecosystem is to let mature (old) forest stands to protect without harvesting. Currently, the protected area has to have its perimeter and stand volume to minimize.

$$maximize \sum_{p=1}^{P}\sum_{i=1}^{I} v_{ip}x_{ip}$$

$$minimize \sum_{p=1}^{P}\sum_{i=1}^{I} v_{ip}y_{ip}$$

$$minimize \sum_{p=1}^{P}\left(\sum_{i=1}^{I} q_i y_{ip} - \sum_{i,j\in J} 2s_{ij}z_{ijp}\right)$$

x_{ip} is a bivalent variable with two states of the unit i

y_{ip} is a bivalent variable with two states of the unit i

z_{ijp} is a bivalent variable with two states of the contiguous units i and j

q_i is a real variable describing the perimeter of the unit i

s_{ij} is a real variable describing the border length between two contiguous units i and j

v_{ip} is a real variable describing the volume of the wood in the unit i in the period p

RESULTS

Table 1. The different groups of harvest scheduling model

Group	weight 1	weight 2	weight 3
A	0.71	0.10	0.19
B	0.06	0.77	0.17
C	0.16	0.22	0.62

Figure 1. Graphical results for different variants with 5% not harvested area and 10% harvest flow; a) group A, d) group B, g) group C

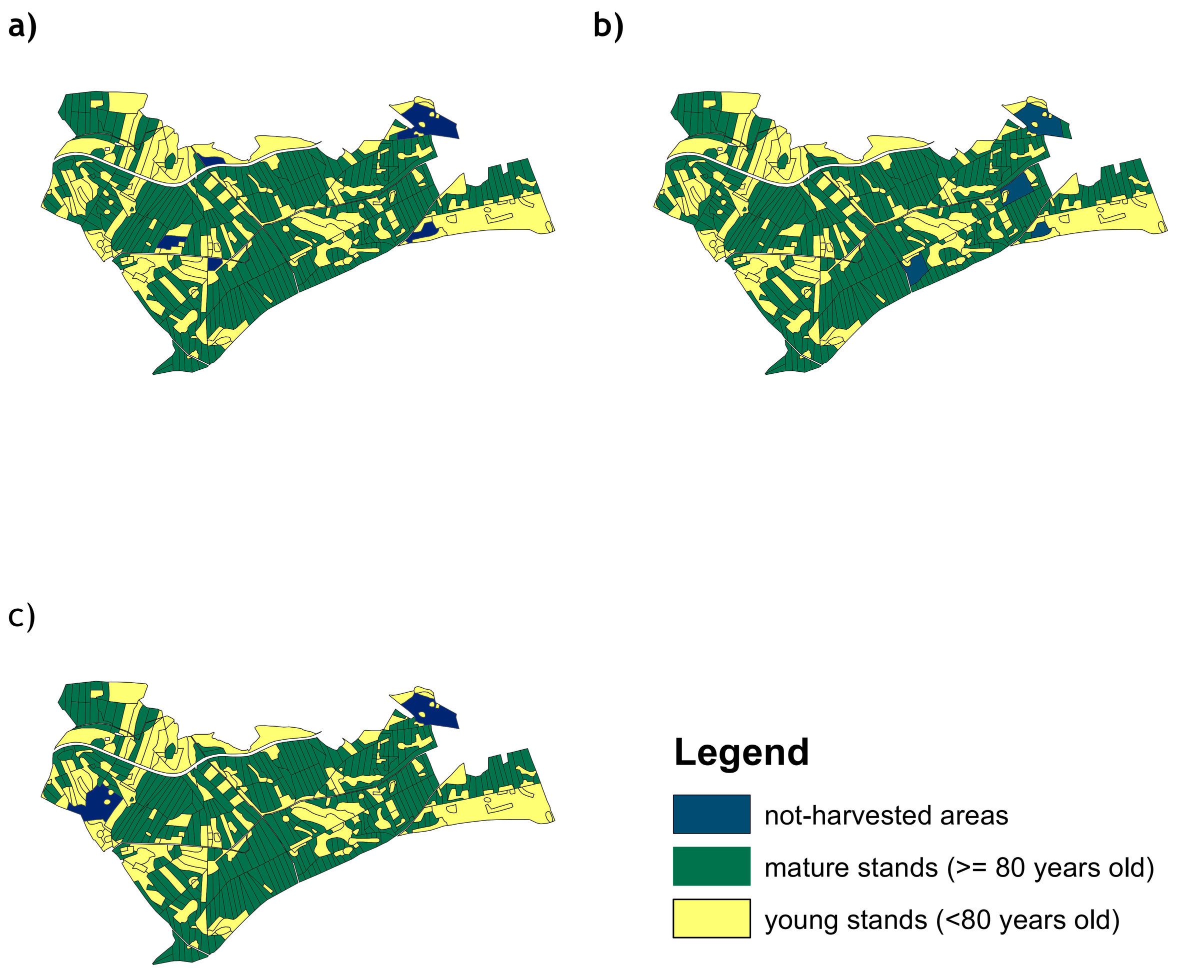


Figure 2. Graphical results for different variants with 10% not harvested area and 10% harvest flow; a) group A, b) group B, c) group C

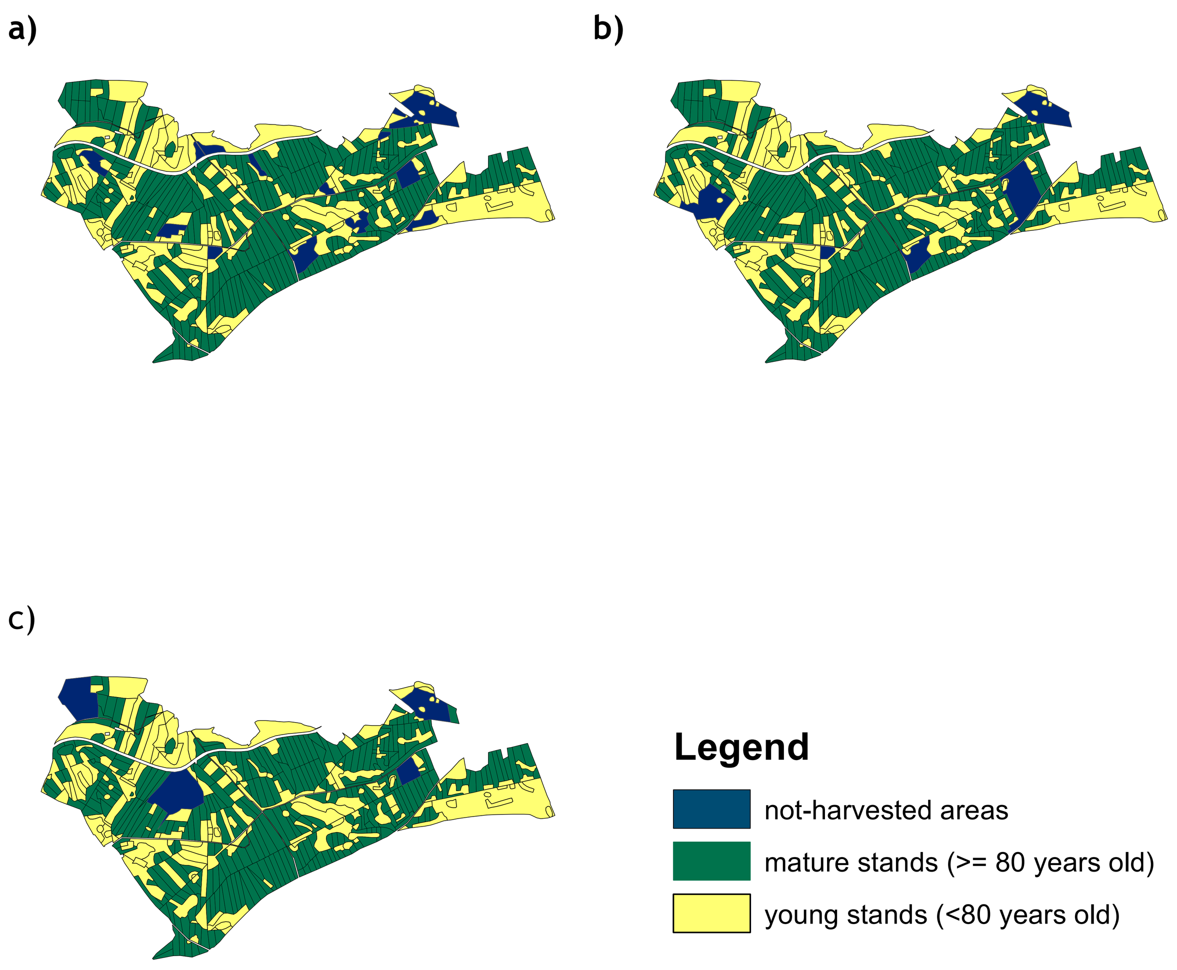
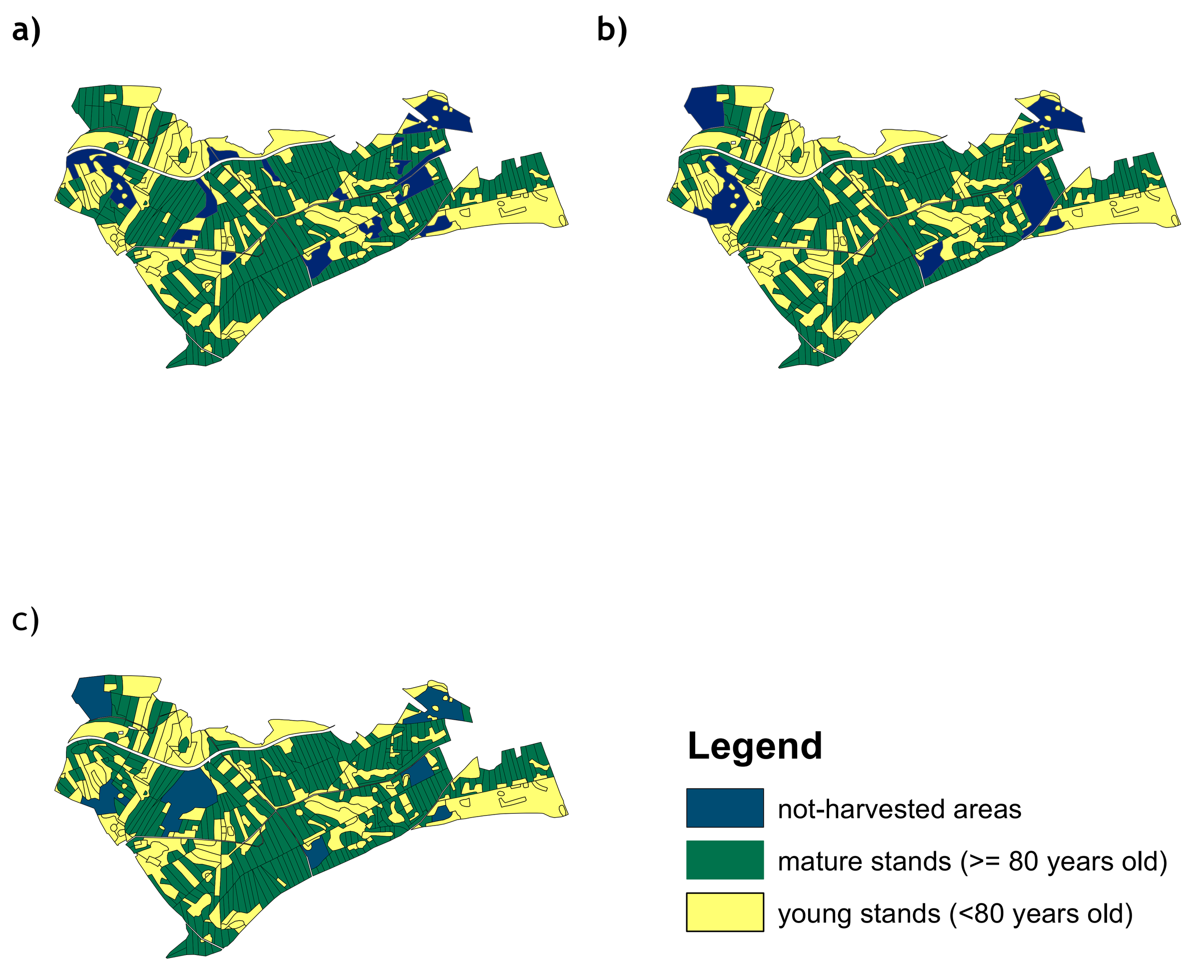


Figure 3. Graphical results for different variants with 15% not harvested area and 10% harvest flow; a) group A, b) group B, c) group C



CONCLUSIONS

An actual situation and a new approach to forest harvesting was presented. In Central Europe, and in the Czech Republic especially, the forest, and thus wood, is a limited asset from an economic point of view. However, the demand for wood these days remains strong. Every forest owner is pushed to provide as much wood as possible, while he is also obliged to fulfil all silvicultural requirements. For forest managers, it is not easy at all to estimate a reasonable amount of wood to be harvested and also meet all of the legal conditions of forest harvesting. Even if these conditions were not given by law, every manager is aware of the importance of forest environmental aspects. The stands themselves could not exist without certain species inhabiting the forest.

The proposed solution is presented within the forest management in the Czech Republic, but it could be implemented in any forest management practice. It shows how to maximize the amount of harvested wood while ensuring the conditions for forest species existence are also preserved. The model of mathematical programming is generally suitable for all forest management areas of s similar size that is very common. Having data describing any forest management area, it is not very complicated or time-consuming to provide the compromise solution and, thus, a better plan of forest harvesting as a service for whoever should desire to improve the effectiveness of forest harvesting.

Further, it could be possible to assume that the protected area would not be static in the long-term planning and would change its position fluently over time. A solution to this problem would be the next stage of our forest harvesting research, with the possible use of dynamic programming.

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