The utilisation of natural resources under environmental aspects exemplified by a model of silviculture

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As technology advances it becomes more and more important to treat nature and regenerative resources with respect and to overcome the antagonism of economic aims and ecological viewpoints. On the one hand it is favoured to exploit natural resources optimally and to maximise the gain, on the other hand there is the risk of destroying ecological systems. This idea of preferably optimal economic use with minimal damage to nature is exemplified in this paper by a model of silviculture.

The following model was formulated by Ching-Rong Lin and Joseph Buongiorno in a 1998 paper. The forest is divided into stands of trees and the condition of a stand at a point in time is called a stand state. Because the space of states is very large the states were aggregated to a few species and size classes. The economic gain from timber harvesting can be easily determined using a simple model of timber prices, the volume of trees felled and the cost of harvesting. As an indicator for the ecological impact biodiversity was chosen, it distinguishes between species diversity, tree size diversity and landscape diversity. The latter is defined as the distribution of states throughout a large landscape. To find a compromise between ecology and economy it is tried to maximise gain under the condition that the diversity values must not fall below a certain limit, which gives the priority to the ecological constraints. An underlying growth model is used to get insights into the growth dynamics of forests. If there is no demand to satisfy, that means the volume of trees felled can be freely chosen taking the diversity values into account, and the harvesting costs are always the same in each stand of the forest, the optimisation problem

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can be solved by applying a Markov decision process which is shown by these authors.
Now stochastic demand is added to the model and the different forest areas can have various transportation costs from the location of felling to the location of consumption, for example the lumber mill. But there are still the same harvesting costs in each stand of the forest. In this case, an economical but myopic management policy seems to be to cut as much as possible in the area next to the lumber mill. This is the location with the lowest transportation costs without violating the ecological restrictions. Then as much as possible is taken from the second nearest and so on. In this case the nearest stands become overused because if there is anything to fell it will be. Whereas the areas far away from the lumber mill will be left intact mostly. If the harvesting costs can vary from one stand to another, for instance caused by difficult terrain, and there is more than one place of demand, it can become very hard to give an analytic solution because the space of solutions becomes very large. For example it is possible to fell in only one area and leave all others intact or to take from every area the same rate or proportionally to the size of the forest area or so on.
The considered approach is now simulation optimisation. Beginning with a valid starting solution another solution is generated and the costs are compared. If they are satisfactory the process stops, if not another solution is generated and so on. The generation of new solutions can be done, for example, by using a genetic algorithm. In this way a solution for the problem of where to fell and how much to fell is generated. Whilst calculating the costs of this solution there is also a transportation problem to solve. This can be done using existing algorithms. It may not be the best solution for the optimisation problem but simulation optimisation delivers a pretty good result.
But this is the solution only for this period. Next step would be to find solutions for the following periods, and create a stationary policy if possible. For this purpose the next periods are simulated in advance. The stochastic demand is given by its distribution function. So the demand of the following periods can be simulated and the costs of the applied policy can be calculated. An emerging problem is what to do if the ecological constraints can not be fulfilled at all. The economic solution would be to fell as much as required. But this can cause the extermination of the tree population. The ecological way would be to fell only as much as the ecological restrictions allow, and at worst the demand is unsatisfied.
Since with purely economic consideration the nature will be damaged unacceptably, the aim of this paper is to find a compromise between

economic and ecological criteria. Obviously, the suggested model is strongly simplified and only a theoretical one. In reality there are much more parameters to take into account.

Literature

Lin, C.-R., Buongiorno, J. (1998): Tree Diversity, Landscape Diversity, and Economics of Maple-Birch Forests: Implications of Markovian Models, in: Management Science, Vol. 44, No. 10, pp. 1351-1366