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PLANNING OF TARGET FOREST TYPES UNDER CLIMATE CHANGE

As a consequence of the forecast global climate change and the resulting shift of site types, the optimal mixture of tree species and the planning of target forest types is of increasing importance. The procedure yields a stand-level optimisation of tree species mixture allowing for manifold restrictions which can be formulated at the level of stands, site type clusters or growth districts, as well as for protected areas or entire enterprise.

Key words: *global climate change, stand-level optimization, target forests, tree growth simulation.*

Overall view of the method. The production of goods in forestry is characterised by extraordinary long production periods. A convenient selection of the tree species can guarantee the essential safety in the production. To find an optimal solution for the choice of tree species is considered as a major target of systematic forestry. At the moment, forestry is confronted with several changes, on the one hand in regard to environment, and on the other hand to social and ecological demands. As a reaction of the prognosis concerning climate change and the resulting rejection of the assumption of stands offering constant conditions, a prudent choice of the tree species is of particular importance. To assess the influence of climate change this study focuses on the scenario A1B of the International Panel on Climate Change (IPCC). Comparing the years 1980/1999 to the period 2090/2099, the annual average temperatures are supposed to increase by 1.8 degrees. This scenario can be considered as a moderate one, in which forestry can adapt to with the help of forest conversion [1 - 3]. Moreover, the aim of an adapted choice of the tree species is not only to avoid risk, but also to take the firms' profit situation in account.

Hence, the planning of target forest types for a forest enterprise helps in reaching a decision of the long-term targets concerning the forest stand. The purpose is to reveal specific types of tree species for each stand, which are the optimum in terms of site and climate adaptability and economical profitability. The target forest is derived by means of an optimisation approach, which mathematically formulates an extremum problem and takes few of other side conditions into account.

The input parameters of the model are site information, tree suitability and the results of growth simulations and their resulting contributions to the profit. A number of individual sites, which provide comparable growth conditions for trees, are fitted together, to so-called 'site clusters'. The tree species suitability for each site cluster was rated in a tree species suitability table according to Aldinger & Michiels [4].

Restrictions on several levels can be taken into consideration for the optimisation of forest management. Strategic targets such as a certain percentage of broadleaves can be taken into account on the level of the whole forest enterprise. Restrictions resulting from protection areas or valuable forest biotopes can be included for certain areas of the enterprise. Thus, target forest planning is an iterative process considering the conditions of the stand, the suitability of the tree species and the estimated profit for the tree species, to achieve a stable future stocking with maximized profit.

Course of the method. The planning of target forest types, as a sustainable element of a long-term regulation of forest development, is oriented on the site that is taken into consideration using the site cluster.

This study focuses on the forest district Eberswalde that covers an area of 40,185 hectares. Certain site information has been categorized by means of the soil type and can be assessed via a detailed data base.

All in all, a number of 450 soil types was taken into account. Combining those with seven several growth districts and three climate levels, respectively, (Tm [medium dry], Tt [dry] and Ttt [very dry] was added later on) leads to around 1,000 different site type areas. Assigning these circa 1,000 variations to ten defined fertility levels (poor to fertile) and 15 defined humidity levels (T..5 "very dry" to O..1 "very swampy") results in 85 site clusters with areas of 0.05 hectares up to more than 5,000 hectares. Only 35 main clusters contain an area of above 100 hectares.

The so-called 'site cluster' composes different site types providing comparable silvicultural possibilities, risks and growth expectations as well as similar natural vegetation types. With the aid of the site cluster, the evaluation of the ecological and economical potential of the forest enterprise is feasible [5].

Tree species suitability table. To ensure the choice of tree species being adapted to the site, the tree species are evaluated in regard to their suitability. Such an evaluation was performed for each site cluster focusing on the criteria of competitiveness, soil conservation, safety, capacity as well as climate change sensitivity according to a modified and amplified approach by Aldinger and Michiels [4].

The evaluation was done on a scale of 0 to 3, with one being below average and three being above the average in respect of the criteria (figure 2). At zero no evaluation was possible. The evaluation is entered in a tree species suitability table, which is supplemented by an overall assessment on a scale of "unsuitable", "sparsely suitable" and "possible and suitable". Finally, a ranking is added at the site cluster which characterises the tree species as main or secondary ones and gives a maximum proportion for each species.

Optimisation of the target forest type. To obtain an ideal achievement of targets and constraints on both, the level of the single stand, and for the whole forest enterprise, the model utilises a linear optimisation approach. Linear optimisation is an iterative process, which can be described as a systematic trial of several combinations, identifying the most favourable one [6].

The aim of the present optimisation approach is also to display the financial consequences of the choice of tree species. This is assured with the help of an objective function, which formulates an extremum problem based on the expected

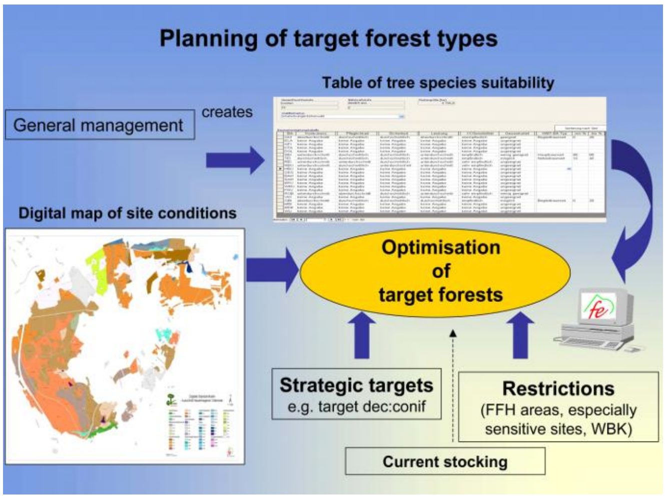

Fig. 1. Elements of the planning of target forest types

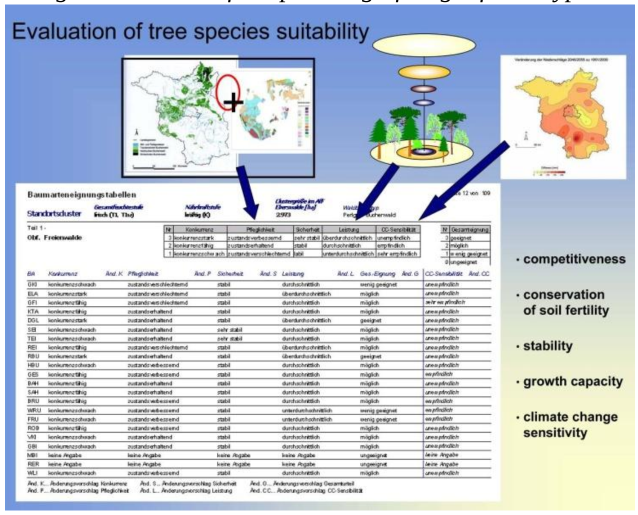

Fig. 2. Evaluation criteria and tree species suitability table

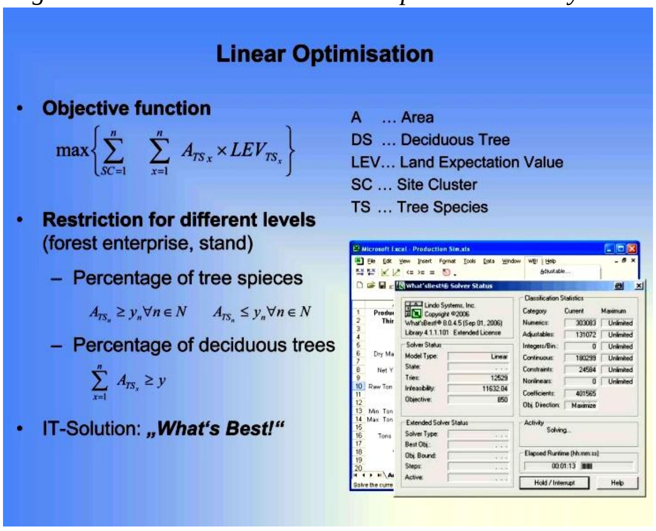

Fig. 3. Structure of the liner optimisation approach

periodic incoming payment and payout of the specific tree species combination. The land expectation value is maximised. Especially, attention is paid to the defined restrictions. As described above, those can be effective on the level of the whole enterprise or for certain parts of it, but the restrictions may also be formulated for single stands. The monetary evaluation of the tree species is based on ideal types of growth development according to the growth simulator BWIN.

Each intervention in the development is monetarily evaluated according to its point in time and with various input interest rates. Thus, it is possible to calculate a capitalised value for each tree species (figure 3).

Results of the target forest planning are: a stand-specific tree species recommendation, detailed data about future tree species distribution on the area of the forest enterprise and the expected benefits.

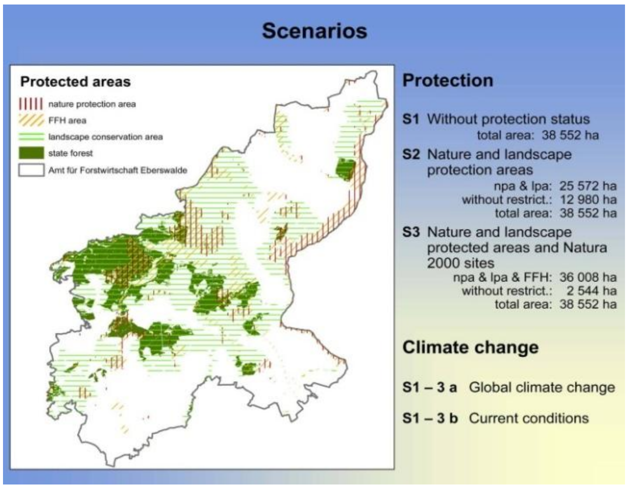

Fig. 4. Studying of the scenarios

Scenarios and results. To formulate a scientifically sound target forest planning for the forest district Eberswalde, various scenarios have been formulated. Those can be seen in figure 4.

Especially, numerous protection areas are a characteristic feature of the landscape mentioned above. Hence, the scenarios are paying attention to them to a different intensity. Restrictions were generally formulated according to the relevant prescriptions. All scenarios were calculated for the two alternatives (a) and (b), whereby alternative (a) represents the site conditions under the influence of climate change (S1a to S3a) and alternative (b) depicts the present site conditions (S1b to S3b).

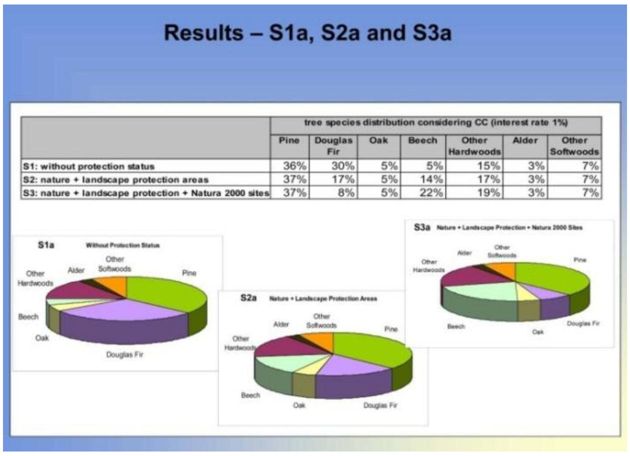

Fig. 5. Tree species distribution based on several scenarios

Figure 5 demonstrates the changing tree species distribution resulting from the different scenarios. Obviously the share of the Douglas fir is strongly dependent on the amount of protection areas taken into consideration.

Subsequently figure 6 reflects the monetary results of the various scenarios. In contrast to the present stocking, which has a calculated land expectation value of -1,041 €/ha, the optimised stocking has a positive land expectation value of 2,289 €/ha, although all kinds of protection areas are taken into account. Both figures are based on the consideration of an input interest rate of 1 per cent.

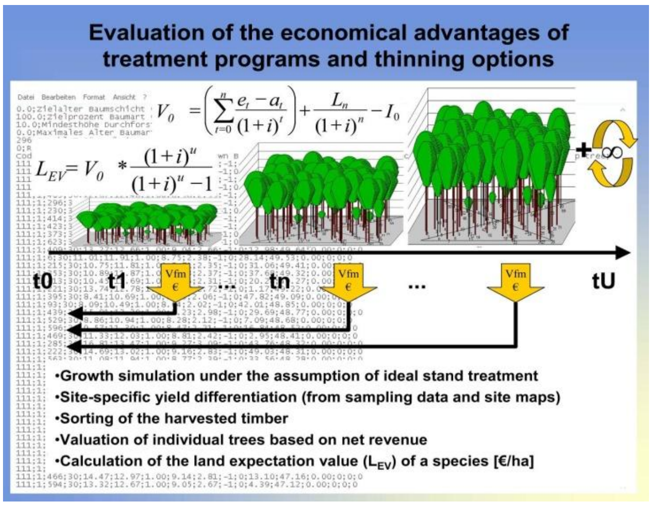

Fig. 6. Method of simulation and monetary evaluation

Scenario S1 reflects a situation without any restrictions due to protection areas. Compared to the prior described scenarios and results a stocking with a land expectation value of 9,821 €/ha could be established hereby. Thus, considerably high costs become obvious regarding the protection areas.

Results - Land Expectation Value				
Interest rate	LEV[€/ha]			
	considering CC			without CC
	1%	2%	3%	1%
S1 - without protection status	9.821	-856	2.493	11.947
S2 - nature + landscape protection areas	6.925	-1.569	2.824	7.938
S3 - nature + landscape protection+Natura 2000 sites	2.289	-2.071	-2.709	5.191
S4 - current stocking	-1.041	-3.416	-3.514	-1.041
Input administrativ costs 125 €/ha/a				

Fig. 7. Result regarding the land expectation value

Moreover, the influence of a climate change adapted planning can be seen. Compared to the planning without regard to climate change the benefits of an adapted planning are generally lower (S1a to S3a). So the difference in land expectation value between alternative a (considering climate change) and alternative b (without climate change) in scenario 3 is only 2,902 €/ha. However, the influence of protection areas as a consequence of political decisions is much more important.

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ПЛАНИРОВАНИЕ ЛЕСОНАСАЖДЕНИЙ В УСЛОВИЯХ МЕНЯЮЩЕГОСЯ КЛИМАТА

Вследствие прогнозируемого глобального изменения климата и в результате смены условий местопроизрастания становится актуальной оптимизация смешанного состава и планирование целевых лесонасаждений. Процесс планирования выражается в оптимизации состава смешанных насаждений, допускающего различные ограничения на уровне насаждений, условий произрастания, категорий защитности, предприятия в целом.

Ключевые слова: *глобальное изменение климата, оптимизация уровней древостоев, целевые леса, моделирование древесного прироста.*

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