OPTIMIZATION OF THE STRATEGY FOR YIELD STOCK MANAGEMENT TOWARDS A NORMAL STATUS FOR REGULAR HIGH FORESTS

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ABSTRACT

The substantiation of decisions in the structural and functional organizing and ma-nagement of the forests has always represented a major concern in the development of the forest management plans. Yet, the management planning decisions are still made, most of them, by using traditional methods. The slow emerging of modern methods in the decision-making process was also due to the low possibilities to quantify the processes and phenomena (biological, technical and economical) in forestry. The progress in the last time opens new possibilities to approach the substantiation of the decisions in this field.

In this context the paper, following the same objective of updating and upgrading the development of forest management plans, approached issues related to the use of some modern methods for substantiating the decisions in the management of the production process in management planning.

Keywords: optimal growing stock, simulation model, allowable cut, mathematical programming

Forest management planning has the task to organize and then manage the forests, structurally and functionally, towards its maximal status of efficiency in accordance with their functions. The organizer task incurs mainly the following:

- developing a concept for organizing and structural-functionally managing the forest;

- strategic planning (specify the works to be performed in the future in order to reach the main objectives);
- tactical planning (specify the works to be performed in each stands for 10 years, in order to reach the strategic objectives);
- monitoring and control of the progress in reaching the established objectives.

In practice, the management of the growing stock towards a normal structure is done only by felling the trees and stands, in a certain rhythm and intensity, and then by regenerating the lands with species appropriate to the established functions of the forests. The constant guiding in time and space of the needed works, in a defined period, for managing the real growing stock towards a status suitable to the established goals is done through management planning. It includes:

- harvest planning that incurs the regulation of tree and stand felling so that social-economical interests are harmonized with the organization ones;
- planning of regeneration works, which lead to the forest regeneration of the felled areas, in accordance with the established goals; obviously, when regeneration is natural, the harvest plan is also a regeneration plan;
- planning of stand tending and management works which leads in time to the optimal structures established by the management goals.

It is noteworthy that only harvest planning represents the means to change the size and structure of the growing stock together with guiding it towards an optimal status (distribution by age classes and diameter categories and suitable arrangement in space).

Two concerns can be noticed in harvest planning: establishing the allowable cut and development of the harvest plan.

Defined as the “wood volume to be harvested in a forest, based on a management plan” (Rucareanu & Leahu, 1982), the allowable cut represents in the same time the forest productivity and a means for guiding (manage) it towards the normal structure. In computing the allowable cut it is considered that it represents a part of the growing stock that will be permanently harvested in order to reach the normal status (the most appropriate status for a maximal, continuous and permanent production). That is why the allowable cut can be higher or lower then forest increment in the period in question.

In computing the allowable cut (for main products) there should be considered both the silvicultural and economical interests which is most of the time in opposition to each other. The mathematical formulas that are used are specific to the concept integrated with applied management planning methods and consider the factors that are essential in the computation of the allowable cut.

Interaction between the increment and development of the growing stock, on one hand and the regulation of the harvest through the computation of the allowable cut and establishing the felling step during a rotation, on the other hand, represents a highly complex process that has several stages. This process is dynamic and its development with the help of computer programming has the disadvantage to lead to static characteristics. That is why it is considered that the computation of the growing stock allowable cut has higher chances by using the dynamic computer programming.

The problem is to establish the system management in each of its stages so that the final status represents the optimum.

The programming provides for the selection technique, of the multitude possible measures, to chose the one that will lead the system from the initial to the final status, so that the function-criterion reaches the optimal value.

Considering what has been said so far, the growing stock can be considered as a physical system, which can be established anytime with the help of the status parameters. The initial status of this system represents the growing stock when the management plan is developed (real stock), and the final status can be considered to be the growing stock at the end of a certain period (decade, period, rotation). In a broad sense, the final status could be the normal status of the growing stock.

The function-criterion is developed as a complex function whose variation is influenced by several factors like stand age, size of allowable cut, value of the standing wood, value of the social functions fulfilled by the stands making up the growing stock, the costs for regeneration and management, etc.

Considering the function-criterion as v, the general mathematical expression will be:

$$(1)\quad v=\sum_{j=1}^{r}F(x_j)+\sum_{i=1}^{n}\left[f_1(x_{1i})+f_2(x_{2i})+\ldots+f_k(x_{ki})\right]$$

where:

- xj represents - variables influencing the function-criterion for the growing stock;
- x1i, ... x2i - variables influencing function-criterion for the component stands.

It is noteworthy that these variables are discreet variables. The real expression of the "v" function can be approximated with the help of the regression methods (multiple non-linear regression).

The duration of the growing stock normalization process can be different from the rotation time. It can be established based both on technical-economic analyses on the real and normal growing stock and on the economic strategy. When the duration is known, the number of stages is computed in relation with the size of the stage. Mainly the management of the real growing stock towards the normal one is based on establishing the allowable cut and the harvesting of the equivalent in the component stands. Based on the above-presented issues the following optimization problem can be developed: "Establish the strategy for the management of the real growing stock towards the normal (optimum) growing stock, so that the function-criterion reaches its optimum". Establishing the mathematical relations and the variable coefficients represents, practically, of "hard-to-solve" problem under the present circumstances, therefore there is a need to use other techniques generated by the operational researches.

That is why the mathematical modeling of the natural forest production and organizing and structural-functional guiding of the forests represents one of the most complex objectives to be achieved in upgrading the management planning. The successful attaining of this objective could provide for the possibility to create simulation models whose use will allow the establishing of the growing stock size and structure during a rotation. Experts and decision making factors will be able to use an useful tool, both in the substantiation of the solutions found in the management plans and in the medium and long term prognosis studies.

Complex researches, carried out in a relatively long period of time, have led to the development of a simulation model to be used in the organizing and structural-functional guiding of the growing stock. The simulation model was called SIMBIOF (SIMularea BIO productiei Forestiere - simulation of the forest bioproduction).

The particularities of the natural forest production process and of the structural functional guiding of the growing stock within the management planning process, have imposed the development of a simulation: abstract, quantifying, mixed, dynamic, non-linear, with a discreet variation and a constant growth. The time factor considered is 10 years and the simulation technique is game-numerical. The simulation regime is in pseudotime (simulation ratio >> 1), and the basic factor of the model is the stand existing in a management-planning unit.

The simulation model, developed in a modular structure, integrates many algorithms capturing the essence of the natural forest production and of the structural functional guiding of the growing stock. They cover, with sufficient precision, three distinct stages of the reoccurring process of efficient stand management in a growing stock:

- development of the forest management planning - with special reference to the technology for substantiating and endorsement of the management planning decisions;
- implementation of the management plan stipulations in the plans for regeneration, tending, guiding and harvesting;
- biometrical development of component stands according to time variation.

A distinct problem of the simulation model use in the organizing of the forest bioproduction is related to the analysis of information resulting from the simulation process. Because we talk about the evolution in time of a cybernetic system, it was needed to find criteria for assessing the evolution of the structure and size of the simulated growing stock as a result of the organizing and leading through management planning. These criteria are mainly related to the guiding of the growing stock towards a normal status under the conditions of experimental changes in the organization framework (economic objectives and management goals) and in the regulation of the forest production. In other words, it must be checked in what way the decisions made during the simulation, on the regulation of the forest production (size of the allowable cut, management plans, etc.) lead the real stock to its optimal (normal) status. All these criteria can be interpreted as a function-objective attached to the simulation model. The criteria integrated with the function-objective include:

- evolution of the growing stock structure (area, volume, increment) by age classes;
- evolution of the growing stock structure by yield classes;
- evolution of the allowable cut size and structure by main products.

Formal description of these criteria needs the following representations:

i - index of the simulation pace; i (N1 = {1, 2, 3, ..., n1}, where n1 is the maximal number of stages established in a simulation;

j - index of the age class; j (N2 = {1, 2, ..., n2}, where

n2 = r(20-1 or n2 = r(10-1 (if the age class is 20 or 10 years), r = rotation considered for the simulated growing stock;

k - index of the yield class; k ({1, 2, ..., 5};

s - index of the species; s (N3 = {1, ..., n3}, where n3 is the number of species existing in the simulated growing stock;

Aij, Vij, Cij - surface, volume and respectively increment of the stands included in the age class j in the simulation step i;

ANij, VNij - surface, volume and normal increment of the age class j in the simulation step i; they are computed according to the rotation, goal composition, normal consistencies and they are modified anytime the regeneration of stand imposes a certain goal composition different from the previous one;

VRi - volume of the real growing stock in the step i;

PNi - size of the computed allowable cut in accordance with the features of the normal growing stock in the simulation step i; PNi is equal in size with the indicative increment of the normal growing stock;

PNis- size of the normal allowable cut for the species in the simulation step i;

Pi - size of the allowable cut of the real growing stock in the simulation step i;

VNi - normal volume of the growing stock in the step i;

Aik - real area of the stands in the yield class k in the simulation step i;

ANik- normal area of the stands in the yield k (in accordance with the site productivity) in the simulation step i; value ANik - is modified anytime there are opportunities in the computation elements (yield class if the regenerated stand differs from the one of the extracted stand);

s- threshold values towards which the families of elements proceed to (Pis)i(N1 and have null values for the species which do not participate in the goal composition.

With these representations the mathematical formalization of the criteria for assessing the evolution of the growing stock becomes:

1. evolution of the growing stock by age classes:
2. evolution of the growing stock by yield classes:
3. evolution of the size and structure of the allowable cut by main products:

$$\sum_{j=1}^{n_2} A_{ij} = \sum_{j=1}^{n_2} AN_{ij} \; ; \quad \sum_{j=1}^{n_2} V_{ij} = VR_i \; ; \quad \sum_{j=1}^{n_2} VN_{ij} = VN_i \quad \text{for } i \in N_1 \quad (2)$$

$$A_{ij} - AN_{ij} = \Delta A_{ij}\,;\ V_{ij} - VN_{ij} = \Delta V_{ij}\,;\ C_{ij} - CN_{ij} = \Delta C_{ij} \quad \text{for} \quad \begin{cases} i \in N_1 \\ j \in N_2 \end{cases} \qquad (3)$$

$$\left(\left|\Delta A_{ij}\right|\right)_{i\in N_1} \to 0\,;\ \left(\left|\Delta V_{ij}\right|\right)_{i\in N_1} \to 0\,;\ \left(\left|\Delta C_{ij}\right|\right)_{i\in N_1} \to 0 \quad \text{for } j \in N_2 \quad (4)$$

$$A_{ik} - AN_{ik} = \Delta A_{ik} \qquad \left(\left|\Delta A_{ik}\right|\right)_{i\in N_1} \to 0 \quad \text{for} \quad \begin{cases} i \in N_1 \\ k = 1, 2, 3, 4, 5 \end{cases} \qquad (5)$$

$$\sum_{s=1}^{n_3} P_{is} = P_i\,; \qquad \sum_{s=1}^{n_3} PN_{is} = PN_i \qquad \text{for } i \in N_2 \qquad (6)$$

$$P_i - PN_i = \Delta P_i\,; \qquad P_{is} - PN_{is} = \Delta P_{is} \qquad \text{for } i \in N_1,\ s \in N_3 \qquad (7)$$

$$\left(\left|\Delta P_i\right|\right)_{i\in N_1} \to 0\,; \qquad \left(\left|\Delta P_{is}\right|\right)_{i\in N_1} \to \alpha_s \qquad \text{for } s \in N_3 \qquad (8)$$

$$\sum_{i=1}^{n_1} \left(\Delta P_i\right)^2 = \min\,; \quad \sum_{i=1}^{n_1} \left(\Delta P_{is}\right)^2 = \min\,; \quad \sum_{i=1}^{n_1} \Delta P_i = \max \qquad \text{for } s \in N_3 \qquad (9)$$

$$P_i - P_{i-1} = D_i \qquad \text{for } i \in N_1 - \{1\} \qquad (10)$$

where: $D_i \leq 0$; $\sum_{i-2}^{n_1} D_i^{\,2} = \min$ (11)

The relations should be interpreted as families of elements arranged in accordance with the index i, elements that have, in normal circumstances, the tendency to reduce continuously the value of the difference module.

The families of elements are $(|\Delta A_{ij}|)_{i\in}N_1$, $(|\Delta V_{ij}|)_{i\in}N_1$, $(|\Delta C_{ij}|)_{i\in}N_1$, $(|\Delta P_i|)_{i\in N_1}$, $(|\Delta P_{is}|)_{i\in N_1}$ processed and analyzed in the convergence of the elements towards the limit value.

The joining of these relations (2) - (11) allows the evaluation of the evolution of the real growing stock, being able to catch the impact of the changes in the bases of management planning and of the regulation of the production process on the size and structure of the simulated growing stock. Under these conditions, SIMBIOF provides, through computer simulation, vital information for establishing:

- the superiority of a production regulation method over another;
- optimal variant within the same regulation method;
- influence of the changes in the bases of management planning (harvesting ages, goal compositions, treatments, rotation) on the size and structure of the growing stock and implicitly on the allowable cut for main products.

The superiority of a regulation method (or of a variant within the same method) is given by achieving, in a minimum time the normalization of the growing stock and by the conditions for implementing the management planning principles and for granting, to the forester, a full freedom to act in the forest. The modular structure of SIMBIOF model allows the use, in the simulation process, of several methods to establish the allowable cut for main products, thus testing their functioning by using criterion relationships.

Within a regulation method, there are several decision variants related to size of allowable cut and to the development of the ten-years plans (for main product harvesting, tending and regeneration operations). The selection of the optimal variant becomes sometimes impossible through traditional means, because there is no practical method to establish the impact a variant has on the growing stock. The SIMBIOF simulation model allows, relatively easily and with an acceptable probability, the selection of that variant that is optimal in accordance with the attached functions-criteria.

A good example in this sense is given by the simulation of a growing stock with an excess structure in harvestable stands and where a certain size of the allowable cut “established” in certain stands leads to a lower or faster rhythm of excess removal. It is known that the removal rhythm influences both the growing stock structure and the future allowable cut. The impact of the removal rhythm in the stands with excess will be reflected in the functions-criteria; it can be emphasized and analyzed at the end of each simulation. The analysis of the resulted indicators for various scenarios will lead to the implementation of the variant which guides the growing stock, in a minimal time, towards a normal status, both in the structure by age classes, species and yield classes and in size of allowable cut, under the provision that the bases of management planning are maintained during the simulation period.

The simulation model opens the possibility to use it in establishing the impact of the stand transfer from one age class to another or of the "double registering", procedures specific to the methods based on age class normalization.

The SIMBIOF model provides for important investigation possibilities in establishing the impact of the change, during the simulation, in the characteristics of the bases for management planning on the size and structure of the growing stock or the size of the forest allowable cut. In this way there can be emphasized the changes resulted from the use of certain solutions for establishing the regeneration or final compositions (goal) on the evolution of the size and structure of the growing stock. In the same way, other experiments can be planed to establish the impact of the change in the stand functions (economic objectives), treatments, system, harvesting ages and rotation.

All the above-presented matters grant to the created simulation model the qualities of an experiment tool for the possible management planning solutions and for the substantiation, using these bases, the decisions endorsed by the management planning studies.

The use of the SIMBIOF simulation model in forest management planning would represent an important step forward in updating the technology for developing management plans; in a short time the model could become an "electronic simulator" vital in establishing the best solutions.

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